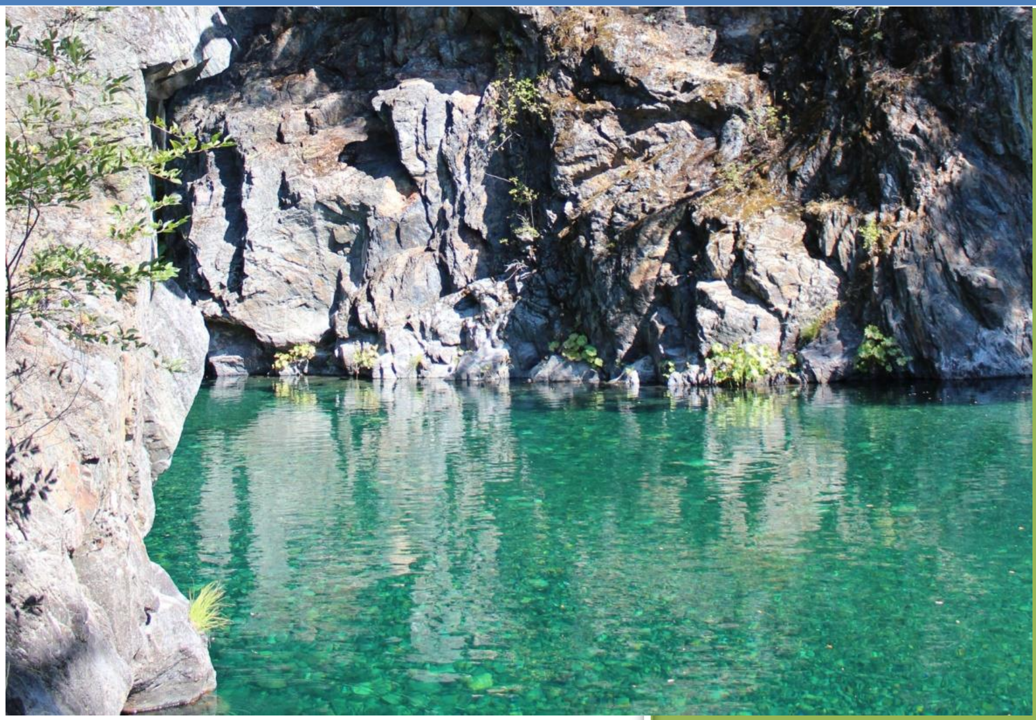
California Water Sustainability Indicators Framework: Assessment at State and Region Scales

Final Report



June 2014

Fraser Shilling
Department of Environmental Science and Policy
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Report to California Department of Water Resources

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Under Agreement # 4600007984, Task Order No. SIWM8

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Cover photo: North Fork of the American River, by Gregory Shilling

Executive Summary

The Water Sustainability Indicators Framework grew out of regional projects developing indicators for water and watershed condition. The California Water Plan Update 2013 (Update 2013) team decided to incorporate sustainability indicators into Update 2013 in response to recommendations from the 2009 Update advisory process. This report describes the work completed in the second phase by the UC Davis team between 2011 and 2013. The first phase (Phase I) involved developing an analytical framework and approach (Framework) for developing and evaluating indicators (updated Framework document is provided as a separate volume). The second phase (Phase II) involved pilot testing the Framework at the state and regional scales and development of a web-based reporting and decision-support tool. The reports documenting work conducted in the two phases are included as articles in the California Water Plan Update 2013, Volume 4 Reference Guide at http://www.waterplan.water.ca.gov/cwpu2013/index.cfm.

The Phase I report describes the progressive development and use of sustainability indicators from vision and goal setting to reporting and knowledge-building. It describes the disaggregation of goals into measurable objectives with tribe, stakeholder, and agency inputs, and the identification of indicators corresponding to the goals and objectives. It describes the use of a novel method for measuring sustainability performance that involves comparing condition to defined desired and undesired targets. The scores that result from the comparison can be reported at various scales, depending on the fineness and extent of the data. Finally, the Framework describes reporting conditions and trends in various formats, including a report card in narrative, tabular, and/or map form. Updated Phase I report is provided as a separate volume.

The Phase II report describes the testing of the Framework at the state scale and the region scale. The statewide reporting is primarily at the Hydrologic Region scale, with additional reporting at finer scales where possible, based on the US Geological Survey's Hydrologic Unit Code (HUC) system for watershed classification. The Santa Ana Watershed Project Authority (SAWPA) region was chosen after consideration of multiple candidate regions because of complexity of the region, availability of a stakeholder process, and capacity of SAWPA to partner with the UC Davis team. The Council for Watershed Health assisted with this regional project, under contract with SAWPA.

The report also includes a "punch list" corresponding to the Task list in the project contract. The work product corresponding to each task item is described and its report or online location described. The project web-site is http://indicators.ucdavis.edu.

Project Task Punch List

Task 1: Select two pilot study regions, the state scale and a planning region, and use both to test the Framework

The state scale was used to test the Framework, based on Hydrologic Region and lower watershed scales. Over a dozen regions were considered for the pilot region. The Santa Ana Watershed Project Authority (SAWPA) region was chosen because of watershed complexity, the presence of a stakeholder process, and technical capacity of the SAWPA organization. The state scale and region scale pilots are described in Sections 3 and 4 of this report.

Task 2: Collect and analyze data for the sustainability indicators. Calculate Water Footprint at state and regional scales.

The indicators collected and analyzed are described in Sections 3 and 4 of this report and the details provided in Appendix A (state scale) and Appendix B (region scale). The state-scale information on individual indicators evaluation is presented on the web-site http://indicators.ucdavis.edu. The region-scale results for SAWPA are presented on their own web-site at http://www.sawpa.org/wp-content/uploads/2014/01/Appendix-A-Assessment-of-the-Health-of-Santa-Ana-River-Watershed.pdf.

During Phase II, the UC Davis/DWR/USEPA team learned that the Pacific Institute was already conducting a California Water Footprint calculation. Rather than duplicate their effort, we engaged Pacific Institute as a sub-contractor and jointly developed a refinement of their estimate of California's Water Footprint. The Pacific Institute led the development of a trends analysis of water footprint and assessment of inter-regional trades in virtual water, while UC Davis led the analysis of variation in water footprint and development of a business case for water footprint to make it clear to various stakeholders the value of this index. The SAWPA was interested in the water footprint as a future tool, but preferred that the water footprint not be included as one of the regional indicators. We did use the counties enclosing SAWPA as a test for population-based (e.g., income) effects on calculated water footprint.

Task 3: Assess conditions and trends for sustainability indicators including distance to targets approach.

Condition/status of all indicators at the state scale and most indicators at the region scale were evaluated using distance to targets. These findings are described in Sections 3 and 4 and Appendices A and B of this report. They are also described for each indicator on the web-site: http://indicaotrs.ucdavis.edu. Because a much larger set of indicators was evaluated than originally discussed (19 for state and 19 for region) and because of limited/no data availability for trends analysis, no trends analysis was conducted. There are water sustainability indicators included in the Phase I Framework (e.g., water temperatures, flows, water use) for which monthly data are available, which is typically needed to conduct reliable trends analysis.

However, the indicators used in the statewide pilot relied on extensive, consistent, and available data. There are very few indicators for which readily-available data are assembled and ready-to-use for statewide trends analysis. The indicators we used did not have sufficient data over time to carry out trends analysis.

Task 4: Identify issues and data gaps for quantifying sustainability indicators for California, including the Water Footprint.

These issues and data gaps are described in Section 6 of this report.

Task 5: Develop and release the DST for displaying data, data analyses, and visualizations. The goals for the DST are i) ensure transparency of process and data availability using a web portal; ii) provide provenance (traceability) for each indicator assessment. iii) demonstrate indicator-based decision-support system as a web tool; and iv) share the results of the USEPA “California Footprint – Sustainability Indicators” projects.

The DST was developed in collaboration with the DWR/USEPA partners who provided a list of desired features for the site. Many of these were incorporated. Some were not feasible within the time and funding constraints of the project and were reserved as potential future improvements. i) The DST provides transparent links between the rationale for individual indicators, the method used to collect, evaluate, and score, and the findings; ii) the DST shows data provenance and provides the data in various forms (http://indicators.ucdavis.edu/resources/spatial-data-indicator-scores), which in the case of the shapefile format includes the raw data; iii) the site provides a catalog of global indicators, a recommended set from the Water Plan Update 2013, and evaluation of 19 indicators mapped at the state and finer scales. For many of these indicators, this is the first time they have been mapped and this is the only online resource in the state that combines these multiple indicators to support water-related decisions; iv) the California Footprint – Sustainability Indicators are presented in detail and linked from the home page.

A summary discussion of the web-based Decision Support Tool is furnished in Section 5 of this report.

Task 6: Participate in 10 to 14 meetings or workshops to discuss strategies, etc., with DWR/USEPA team and other stakeholders.

Fraser Shilling participated in 26 (2012) and 12 (2013) meetings (38 total) with USEPA/DWR and other stakeholders (e.g., SAWPA, CWH, SGC).

Task 7: At different stages present progress reports for review and feedback to DWR, USEPA, and interested stakeholders at 3 to 4 workshops.

Fraser Shilling presented approach and findings during at least 4 SWAN/PAC/TAC/Plenary meetings in 2012-2013.

Task 8: Prepare a draft report that summarizes the outputs from Tasks 1 – 6, identifies data gaps, and recommends next steps, including recommendations for a functioning web-based DST building upon Task 5.

A draft report on Phase II work and a companion updated draft report on Phase I work were prepared for review and feedback by DWR and USEPA.

Task 9: Prepare a final report for DWR that includes Phase I and II products; description of methods and findings; issues and data gaps; reviewer comments and responses to comments; and recommendations for future work, including on a full-fledged DST; and a reference bibliography.

The present report on Phase II work and a companion updated report on Phase I work fulfill this Task after incorporating feedback from DWR and USEPA.

Task 10: Assist DWR with hosting a 2-day meeting on water sustainability indicators.

Assisted DWR in carrying out a meeting with SWRR to satisfy this task.

California Water Sustainability Indicators Framework: Assessment at State and Region Scales

June 2014

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1. Executive Summary

Measuring environmental, social, and economic conditions and influences on these conditions are an important part of knowledge-building and adaptive management. The California Water Sustainability Indicators Framework (Framework), developed as part of the California Water Plan (CWP) Update 2013, brings together water sustainability indicators that will inform us about water system conditions and their relationships to ecosystems, social systems, and economic systems. The Framework is intended to support reporting of indicators to a wide array of water and environmental stakeholders, the public, and decision makers to build knowledge and to enhance adaptive decision-making and policy change. Detailed information on the development of the Framework is presented in a companion document titled “The California Water Sustainability Indicators Framework.”

Phase II of the project consisted of using the process and a set of indicators at the state and regional scales as a proof-of-concept for the Framework. The partner entity and the region chosen were the Santa Ana Watershed Project Authority (SAWPA) and the Santa Ana River Watershed. In partnership with the Council for Watershed Health, goals, objectives, and indicators were chosen and defined as part of the SAWPA’s One Water One Watershed (OWOW) 2.0 process. Data was collected for a sub-set of indicators and corresponding conditions were calculated. Similarly, members of state agencies that are partners in the Water Plan Update 2013 were asked for their suggestions of indicators that could help assess progress toward the sustainability goals/objectives in the Sustainability Indicators Framework. Data was collected for a sub-set of indicators relevant at the state/hydrologic region scale and their conditions were calculated. For both the region and state scales, conditions were normalized relative to desired and un-desired conditions. This normalization results in indicators being comparable with each other and amenable to aggregation.

1.1. Integration with California Water Plan

The sustainability indicators framework was designed to be used in conjunction with other aspects of the Water Plan: Progress Reports, Regional Reports, Resource Management Strategies, Scenario Planning, and other components. Progress reporting under the Water Plan is intended to measure performance of management actions. The terms performance measures and indicators are closely related in that performance measures are indicators of management performance and performance measures tell us about performance of ecological, social, and economic systems. The Framework was designed to integrate sustainability indicators and performance measures into a single Water Plan reporting system. The indicators in the state pilot were reported at the hydrologic region, as well as finer scales. This allows reporting of conditions within Regional Reports according to state or regional targets for condition. One of the selection criteria for candidate indicators was their relationship with Resource Management Strategies (RMS). As one of the main vehicles for implementation of the Water Plan, RMS are important tools in implementing sustainable practices. Indicators measuring effectiveness of

RMS will be a critical knowledge-gaining and decision-support tool. Scenario planning has involved projecting future water use, supply, and management responses. Many of the input data and model outputs are indicators in their own right and thus can be used to link measuring sustainability with planning for future sustainability.

1.2. Integration with California Indicator Efforts

California is on the verge of adopting a full suite of indicator systems to cover many aspects of social, economic, and environmental conditions. These systems are within statewide plans and include the California Transportation Performance Reports (Caltrans), the California Wildlife Action Plan (California Department of Fish and Wildlife), California Health Communities Indicators (CDPH), Strategic Growth Council Regional Reports (SGC), Marine Protected Area monitoring (Ocean Protection Council), MyWaterQuality reporting web site (California Water Quality Monitoring Council), and the California School Accountability Report Card (CDE). The Water Plan Update is a collaborative plan developed among over two dozen California agencies and Departments. Because of how it is built, the indicator system described here could be used within any of the other state planning processes. Assembling indicators from the state's plans and efforts by others in the state into one coordinated system could reduce duplication and improve prioritization of policy development and resource allocation.

2. Overview of the Water Sustainability Indicators Framework

> "*California water management must be based on three foundational actions: use water efficiently to get maximum utility from existing supplies, protect water quality to safeguard public and environmental health and secure the state's water supplies for their intended purpose, and expand environmental stewardship as part of water management responsibilities.*"
>
> California Water Plan Update 2009, Volume 1, page 5-20.

2.1. Water Sustainability Domains

Water sustainability domains, as used in the Sustainability Indicators Framework, refer to the components of the natural and artificial water system. Domains are also used to organize indicators so that the combined scores of indicators within a domain can be used to understand specific areas of concern (e.g., water quality).

2.2. Water Sustainability Goals & Objectives

Another way to organize indicators is according to our goals and objectives for natural and human systems (Table 1). It is possible to attach indicators to goal or objective statements and evaluate how close we are to achieving them. This evaluation is useful as an assessment of condition, as well as a decision-support tool to inform future investments of regulatory, institutional, funding, or other types of effort.

Table 1. Water sustainability goals and their relationship to other elements of the Water Plan

Proposed Water Sustainability Goals	**Connection to other Water Plan Elements**
Goal 1. Manage and make decisions about water in a way that integrates water availability, environmental conditions, and community well-being for future generations.	CWP Objectives 12,15,16
Goal 2. Improve water supply reliability to meet human needs, reduce energy demand, and restore and maintain aquatic ecosystems and processes.	CWP Objectives 2,3,7,8,9,12; RMS Reduce demand; Increase water supply
Goal 3. Improve beneficial uses and reduce impacts associated with water management.	CWP Objectives 7,13,14; RMS Operational efficiency
Goal 4. Improve quality of drinking water, irrigation water, and in-stream flows to protect human and environmental health.	CWP Objectives 4,7; RMS Water quality
Goal 5. Protect and enhance environmental conditions by improving watershed, floodplain, and aquatic condition and	CWP Objectives 5,7; RMS Natural Resources

processes.	
Goal 6. Integrate flood risk management with other water and land management and restoration activities.	CWP Objectives 1,6,8; RMS Improve flood
Goal 7. Employ adaptive decision-making, especially in light of uncertainties, that support integrated regional water management and flood management systems.	CWP Objective 1,10,15,16,17; various RMS

2.3. Water Sustainability Indicators

An important component of the Water Plan Update 2013 is the development of a useful set of indicators to help find out how sustainable California is in terms of water.

Detailed information on the Framework as well as indicators development process is presented in a companion document titled "The California Water Sustainability Indicators Framework." The companion document is included as an article in the California Water Plan Update 2013, Volume 4 Reference Guide at http://www.waterplan.water.ca.gov/cwpu2013/index.cfm. The 120 proposed indicators are listed and described in Appendix D of this companion document. The indicators are also published on the Sustainability Indicators Framework website: http://indicators.ucdavis.edu/indicators.

3. State Pilot Test of the Sustainability Indicators Framework

In order to evaluate the utility of the Framework across the critical geographies of the state, indicators from the Framework were evaluated at the state and regional scales. This section describes the pilot test at the state scale and the following section describes the pilot test at the region scale.

3.1. Selection of Indicators for State Pilot

Indicators were selected for the state scale that had relatively uniform data availability for the state and that could be used to populate most of the Framework goals and domains (Table 2). Indicator selection was vetted with the inter-agency Water Plan team at various stages of development. These indicators represent a broad cross-section of ways to evaluate water sustainability in California, but do not capture all aspects of sustainability that individual organizations or regions may consider critical. The evaluated indicators could be built upon in subsequent evaluations and a picture of water sustainability could begin to form.

Table 2. The state pilot indicators and indices. The "sustainability goal" listed in Table 1 and corresponding to each pilot indicator is shown in the last column.

Indicator Name	Brief Description	Sustainability Goals
Aquatic Fragmentation	Stream fragmentation by road-crossings	5
Baseline Water Stress	Annual water withdrawals as a % of total available flows	1,2
California Stream Condition Index	Composition of invertebrate community compared to expected	5
Geomorphic Condition	Potential degradation of geomorphic processes and condition from land development	5,6
Groundwater Quality-CalEnviroScreen-Groundwater Threats	Threats posed to groundwater supplies from underground contamination	4
Groundwater Quality-Nitrate	Nitrate concentrations in groundwater supplies	4
Groundwater Stress	The ratio of groundwater withdrawal to recharge rate	2
Historical Drought Severity	Frequency and severity of historical droughts	2,5
Historical Flooding	Frequency and severity of historical flooding	6
Interannual variability	Variation in precipitation from year to year	2,5,7
Native Fish Species	Composition of fish community compared to expected	5
Public Perceptions of Water	Public views of current and future water supplies, ecosystem protection, and water quality	7

Return Flows	The % of available water used and discharged upstream	2,3
Threats to Amphibians	Current threats to amphibians from water and land use	5
Upstream Protected Lands	Proportion of landscape upstream from a point that is protected	2,4
Upstream Storage	Amount of water storage upstream from uses (e.g., cities)	2,3
Water Footprint	Consumption and impact on water from producing goods and services used by a population	1,2,7
Water Quality Index	Potential impact to water quality from land development	4
Water Use and Availability	Water use and supplies to meet social and economic needs	2

3.2. Findings for State Pilot

A summary of findings for the pilot test at the state scale for the indicators is presented below, while detailed results are furnished in Appendix A.

California Stream Condition Index

The presence and abundance of aquatic plants and animals can provide an indication of waterway and landscape disturbance, geomorphic conditions, appropriate water availability, and water quality. The State Water Resources Control Board has adopted the California Stream Condition Index (CSCI) as a defensible and useful indicator of water quality and stream disturbance. It is based upon comparison of an observed assemblage of benthic macroinvertebrate (BMI) with an expected assemblage, based upon comparison with reference streams.

The desired condition is for streams to support native species and natural processes, including healthy trophic interactions and the full complement of expected species.

Our analysis indicates that in general, streams in mountainous areas where CSCI evaluations have occurred are in good shape, while urban and agricultural area streams tend to be in moderate to poor condition. A comparison of the South Coast and North Coast hydrologic regions shows that in hydrologic regions that are highly urbanized, the CSCI scores are lower than hydrologic regions with low urbanization (Figure 1).

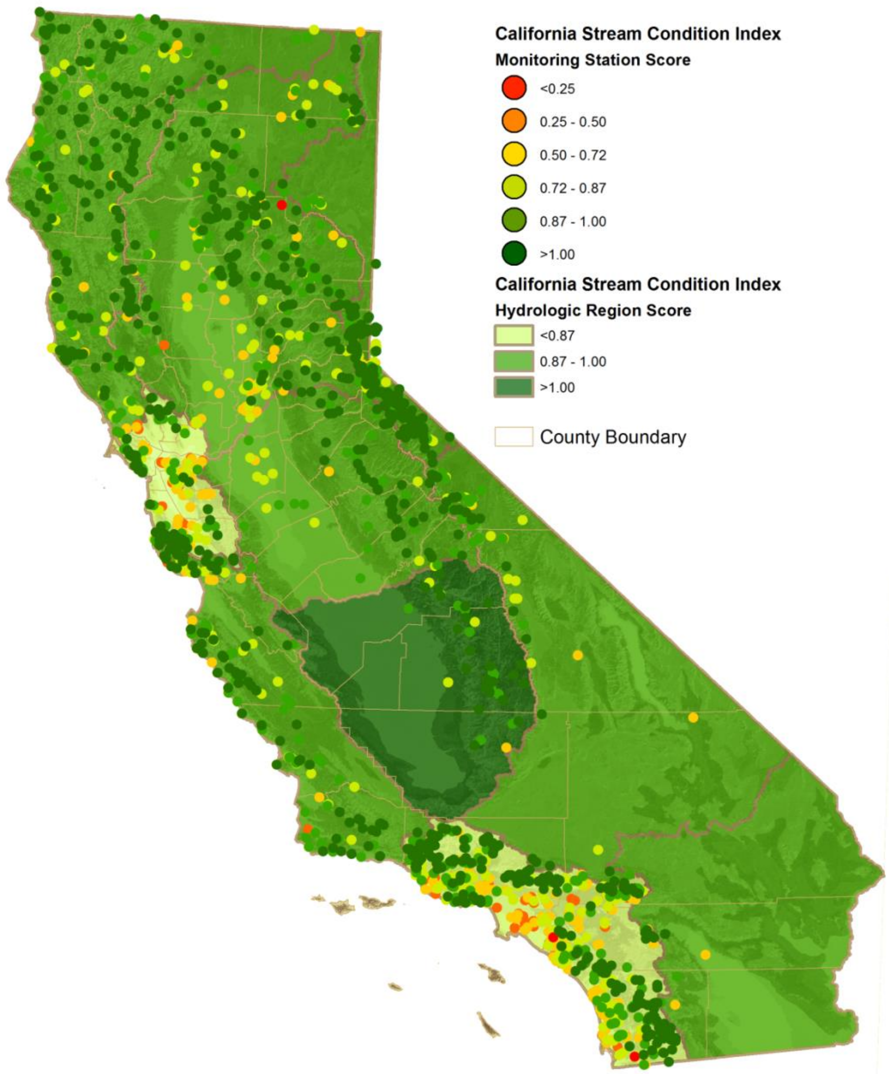


Figure 1. California Stream Condition Index (CSCI) scores for individual monitoring stations and for hydrologic regions

However, summarizing the CSCI data from points to larger extents, such as hydrologic regions, may over-estimate CSCI scores and give the impression that streams in certain regions are in better condition than they are likely to be. As shown in Figure 1, evaluation of streams in the Tulare Lake hydrologic region occurred in the less-disturbed foothill and mountain watersheds, not in the urban agricultural areas. This has given the Tulare Lake region the highest monitoring score relative to all the other hydrologic regions.

Groundwater Quality

Three indicators were chosen to represent groundwater quality: 1) nitrate concentration as a direct measure of quality; 2) whether or not an area/community has safe drinking water

(SWRCB, 2013); and 3) whether or not an area contains "threats" to groundwater according to CalEnviroScreen (CalEPA, 2013).

Our evaluation found that roughly a third of the state has some threat or actual degradation of groundwater quality mostly concentrated in agricultural and urban areas (Figure 2). More detailed analysis on the nitrate indicator as well as results for other two groundwater quality indicators are provided in Appendix A.

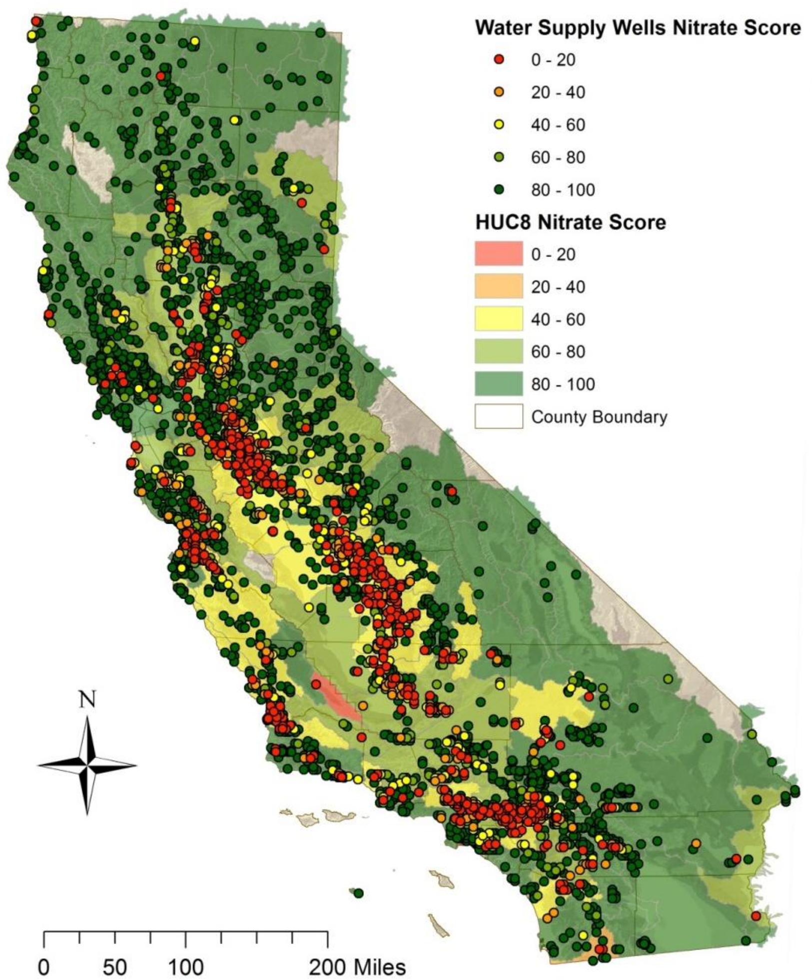


Figure 2. Scores for nitrate concentrations sampled at water supply wells in 2012 and corresponding scores for HUC-8 watersheds

California's Water Footprint

The water footprint is the sum of the water used directly or indirectly to produce goods and services consumed by humanity. Agricultural production accounts for most of global water use, but drinking, manufacturing, cooking, recreation, washing, cleaning, landscaping, cooling, and processing all contribute to water use (Hoekstra et al. 2011). By measuring and understanding the many ways that Californians use water, whether it is through pipes or from food production, we can reduce the risks and uncertainties associated with certain ways of using water in production and improve our water sustainability.

The assessment of California's Water Footprint indicates that California imports over two-thirds of its virtual water through products made elsewhere in the world, including other states. This stands in contrast to 20 years ago when California consumed the same proportion from products made in the State (Figure 3.) It indicates that California is increasingly dependent upon goods from other states and countries. As water becomes scarcer, it raises the possibility that California could be negatively impacted from both political or economic turmoil and poor environmental conditions in other parts of the country and the world.

A more extensive assessment of California's Water Footprint is presented in Appendix A.

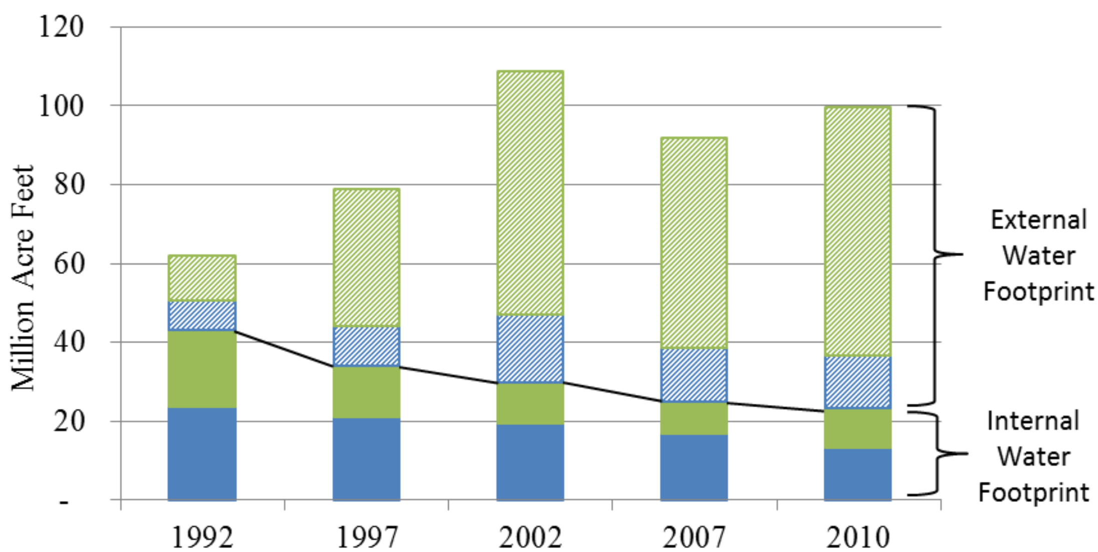


Figure 3. The total water footprint of goods and services consumed within California (million acre-feet) between 1992 and 2010

Aquatic Fragmentation

Aquatic fragmentation is the potential hydrologic alteration caused by diverse type of structures, such as dams, weirs, drop structures, and other man-made systems that modify hydrologic flow. Aquatic fragmentation has direct and indirect effects on the ecology, diversity and abundance of a variety of aquatic organisms.

Our analysis indicates that because of the high density of roads in the state, aquatic fragmentation is a problem across the state. In our evaluation, about half of the state received a score in the lowest category of 0 – 20 (Figure 4).

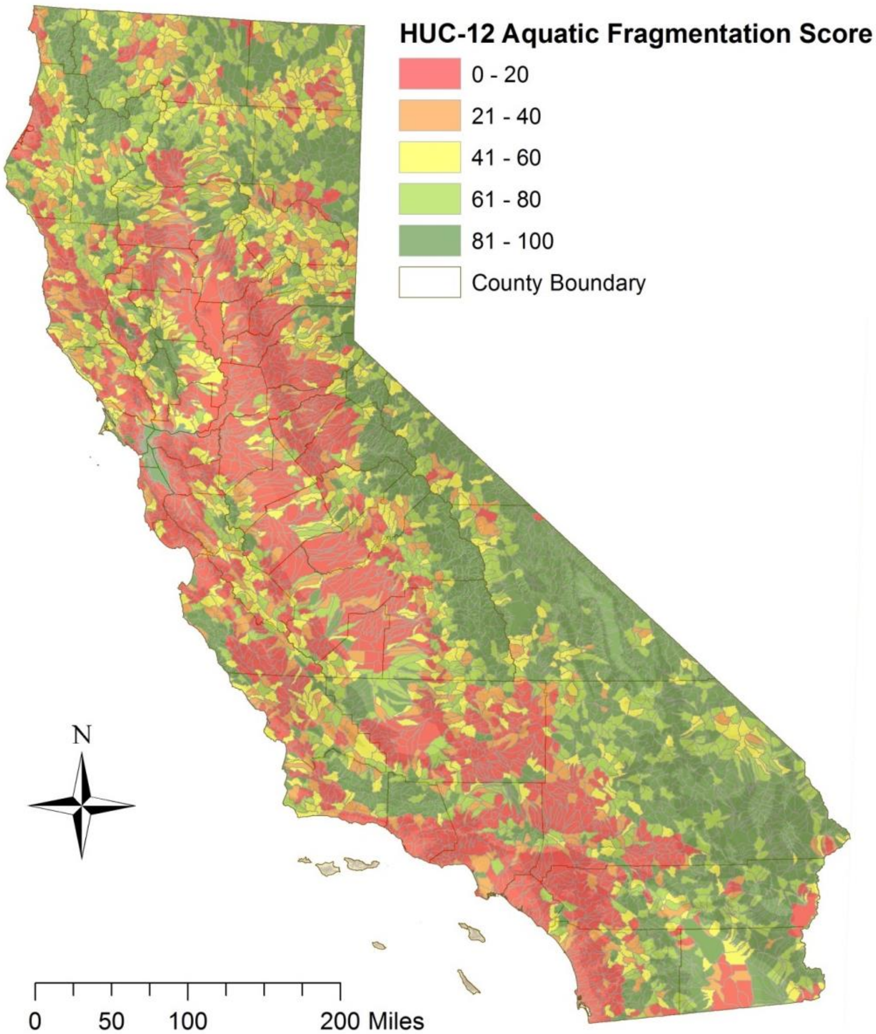


Figure 4. Aquatic fragmentation scores for HUC 12 watersheds

Geomorphic Effects of Impervious Surfaces

Impervious surface is a measure of land cover. The greater the proportion of watershed with impervious surfaces, the greater the likelihood of geomorphic processes and conditions being degraded due primarily to modifications of stormwater runoff dynamics.

Our analysis indicates that out of 4,637 watersheds, the mean percent impervious area for the state of California is 2.6%, with mean percent impervious area of watersheds ranging from 0-68.8% impervious area. Figure 5 shows that streams in the San Francisco Bay and South Coast hydrologic regions are more likely to experience modified geomorphic processes given their highly urbanized development. Percent change in impervious land cover across California between the years 2001 and 2006 as well as information about the interpretations of the National Land Cover Database (NLCD) analysis is furnished in Appendix A.

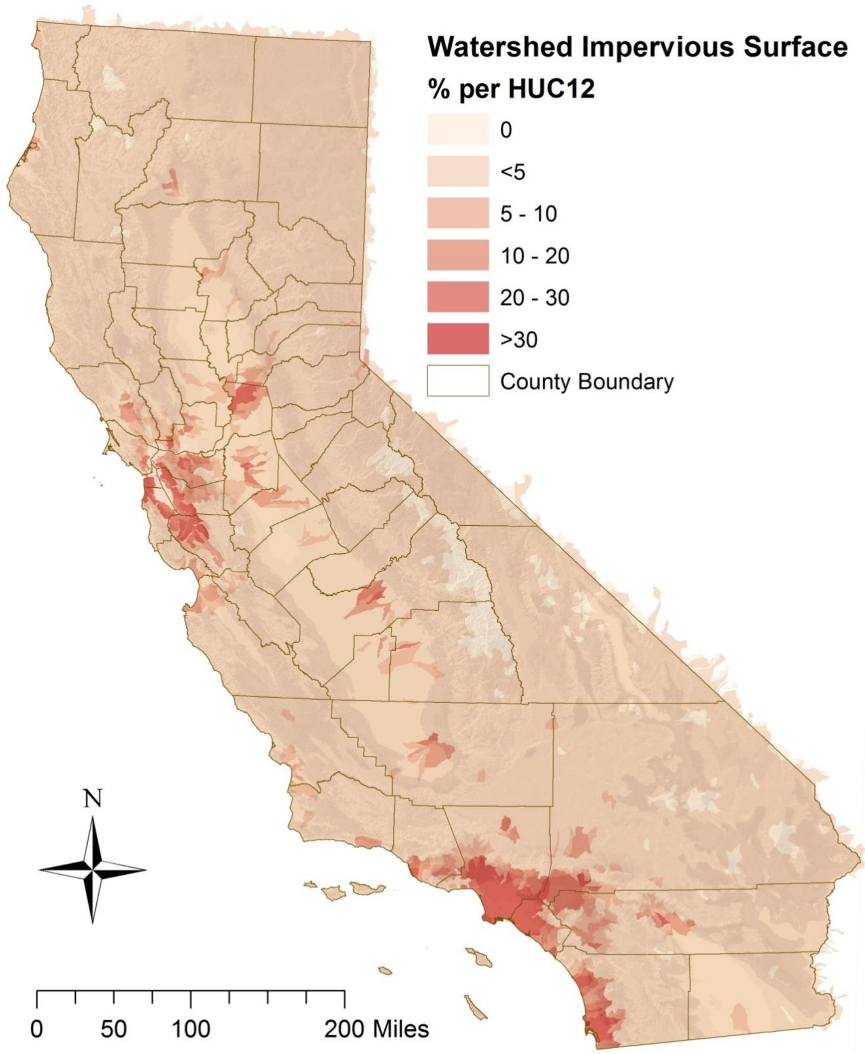


Figure 5. Illustration of the mean percent impervious cover for watersheds in California

Water Quality Index (Impervious Surface)

Water quality is affected by impervious surface development in watersheds. The more impervious surfaces are developed, the greater the chance that water quality will be degraded. This indicator serves as a potential measure of impact of development on water quality, which can have secondary effects on drinking water quality and ecosystem health.

A comparison of Figure 5 and Figure 6 shows that lower water quality scores are found in areas where land imperviousness is the highest.

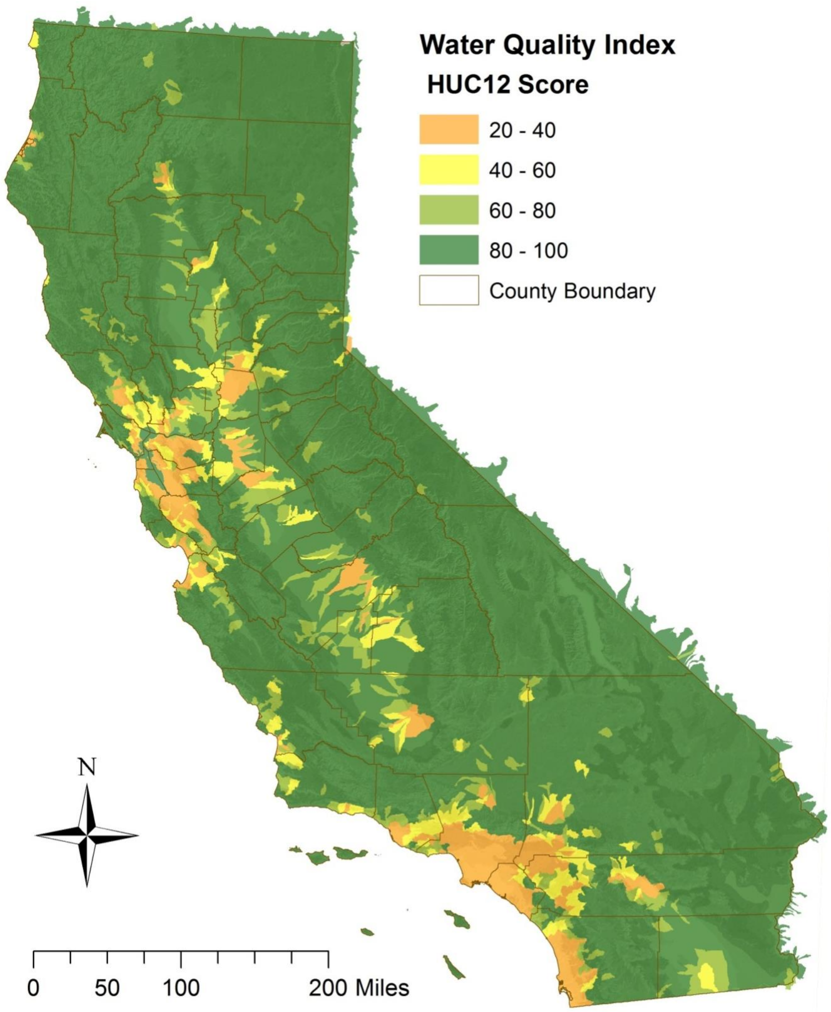


Figure 6. Illustration of the Water Quality Index scores for watersheds in California for HUC12 watersheds

Native Fish Conservation Status and Community Diversity

California has 129 native inland fishes, of which 63% are endemic to the state (Moyle et al 2011). Fish communities are important elements of the state freshwater ecosystems and their status and composition represent good indicators to evaluate disturbances over time. The fish conservation status indicators provide useful information on threats to native fish and the causes of decline.

The state-wide assessment of fish populations indicates that of the 129 freshwater fish native to California, five percent are extinct as of 2010, while 77 percent are either ESA listed or marked as species of special concern (Moyle et al. 2011). More detailed information on this assessment is provided in Appendix A.

Public Support for Water Measures

A common practice among sustainability indicator systems is to measure public awareness and support for environmental protection. This can be measured in several ways, including knowledge of environmental issues, expenditures to support the environment, and voting for pro-environment measures. Public awareness and perceptions of the role water plays in their lives and in the environment can affect how people vote to support candidates, taxes/assessments, and bond issues.

Three metrics were used to gauge public perceptions of current and future water supply management: 1) security of a region's water supply, 2) threat of climate change effects on water availability, and 3) appropriate management strategies to sustainably manage water systems in the future. All three metrics indicate that the majority of the public are concerned about the region's water supply and the threat of climate change on water supplies and support the management of current and future supplies more efficiently. More detailed information on the data used and results obtained from this analysis are presented in Appendix A.

Water Supply and Use

Water supply is the total water volume in annual runoff and from groundwater sources for all human and non-human uses. Water supply is defined here as the water available for human uses, while water use is the amount of water delivered and used as measured or estimated by various local, state, and federal agencies. The ratio of water used to water supply provides a useful indicator of how sustainable society's water use over time.

The assessment of California's surface water supply shows that surface water supply varies from year to year. However, water use remained relatively stable from 1985 to 2005 based upon US Geological Survey and DWR data. More detailed information on water supply and use assessment is provided in Appendix A.

Aqueduct 2.0 Project Water Indicators

The Aqueduct 2.0 is a project of the World Resources Institute, which was the source of the indicators presented. These indicators are based on a set of fairly low resolution data presenting a relatively coarse picture about the selected indicators.

Ten Aqueduct 2.0 project indicators were utilized for the Framework, which include 1) Baseline Water Stress; 2) Interannual Variability; 3) Seasonal Variability; 4) Flood Occurrence; 5) Drought Severity; 6) Upstream Storage; 7) Groundwater Stress; 8) Return Flow Ratio; 9) Upstream Protected Land; and 10) Threatened Amphibians, which is a measure of the percentage of freshwater amphibian species classified by IUCN as threatened.

More detailed information on assessment of the Aqueduct 2.0 project indicators is presented in Appendix A.

3.3. Discussion of Results / What-If Scenarios

An important aspect of the scoring system used is that resulting scores will vary depending on the targets chosen for the desired and undesired condition. This aspect of the system was evaluated using “what-if” scenarios with three indicators: California Stream Condition Index (CSCI), Nitrate in Groundwater, and the Water Footprint. In each case, three different scoring scenarios were used to compare the results when targets changed.

A. California Stream Condition Index

As noted previously, this index originates from a standard approach of comparing benthic macroinvertebrate metrics at “stressed” sites with metrics at reference sites. There has been a lot of statistical analysis of the metrics data from more than 2,000 sites around California. At each site, the CSCI was calculated by the developers of the index (Mazor, Ode et al., 2013) and across all reference and stressed (i.e., disturbed by land or water activities and structures) sites. We calculated the mean CSCI value for watersheds of different sizes for USGS HUC-12 (small) to HUC-8 (intermediate) and for DWR hydrologic regions.

Three “what-if” scenarios were used. The first scenario stipulates that the best score (100) is for waterways/watersheds that have CSCI values at or greater than the mean for reference sites. A score of 0 is equivalent to a CSCI value of 0. The second scenario stipulates that the best score (100) is for waterways/watersheds that have CSCI values greater than the lower end of the reference site scale (0.87) and again sets a score of 0 at a CSCI value of 0. The third scenario stipulates a score of 100 for CSCI values at or greater than the reference site mean and a score of 0 for CSCI values below the mean stressed site value (0.72) minus the variance for stressed sites (0.22), which equal 0.50.

Scenario 1: All CSCI values above the mean for reference sites (1.01) get a score of 100 (Figure 7.A); CSCI values between the reference mean and the low-end of the reference scale (0.87) get a proportional score down to 90 for a value of 0.87; CSCI values between the mean stressed site value (0.72) and the low-end reference value (0.87) get a proportional score between 50 and 90; CSCI values less than the mean stressed site value (0.72) and 0 get a proportional score. The map (Figure 7.B) shows the result of this scoring approach.

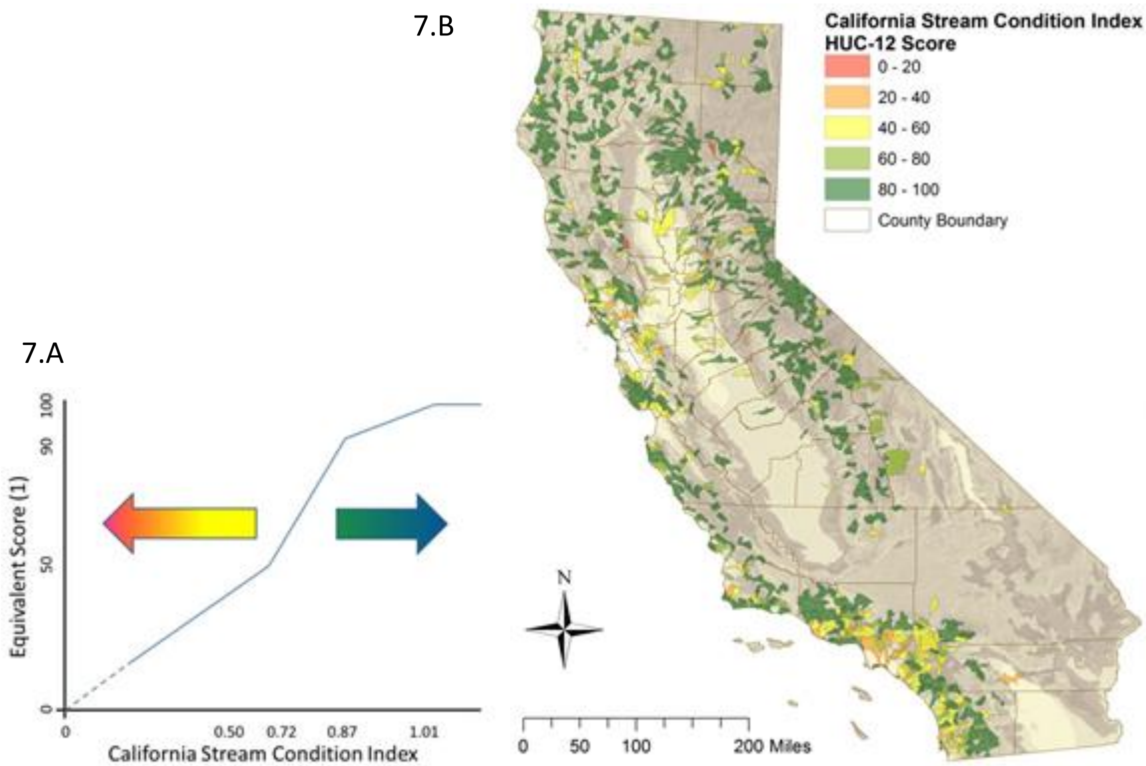


Figure 7. A) Scoring curve (Scenario 1) and B) Results (HUC 12 scale) of Scenario 1 scoring curve for California Stream Condition Index.

Scenario 2: All CSCI values above 0.87 get a score of 100 and values below 0.87 get a proportional score down to a value of 0. The map shows the result of this scoring approach.

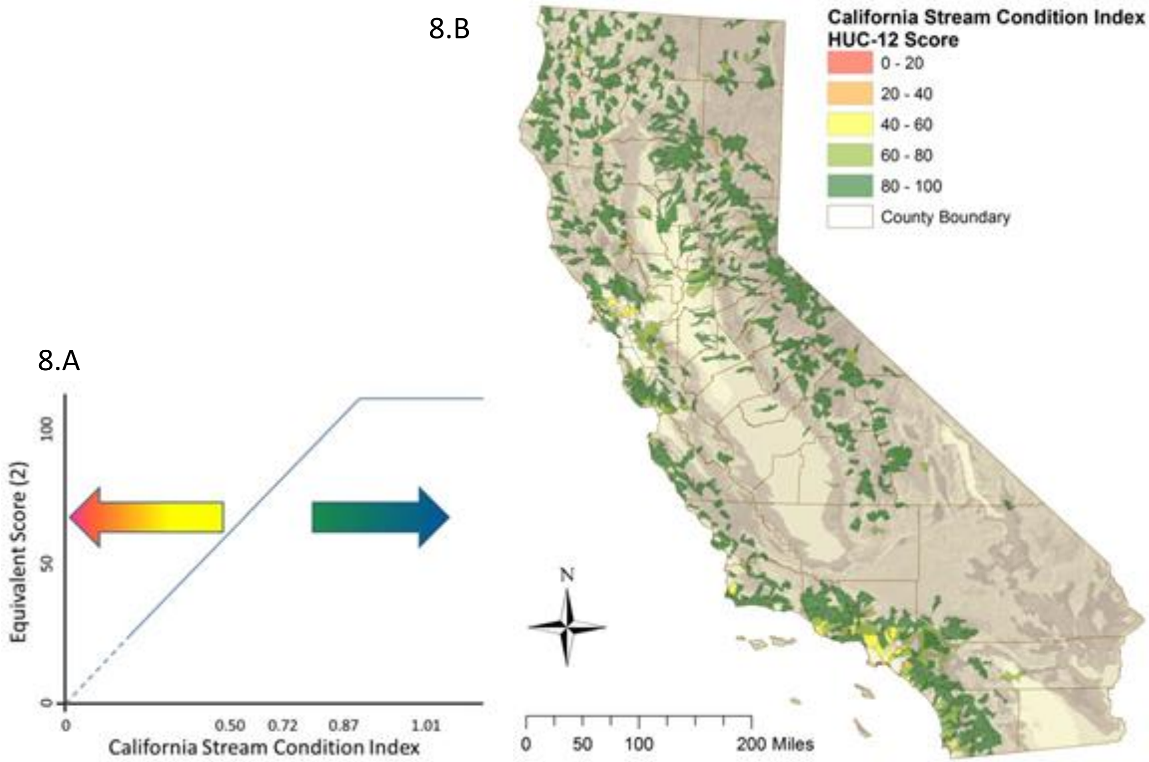


Figure 8. A) Scoring curve (Scenario 2) and B) results (HUC 12 scale) of Scenario 2 scoring curve for California Stream Condition Index.

Scenario 3: All CSCI values above the mean for reference sites (1.01) get a score of 100; CSCI values between the reference mean and the low-end of the reference scale (0.87) get a proportional score down to 90 for a value of 0.87; CSCI values less than 0.87 receive a proportional score down to a score of 0 for CSCI value of 0.50, which is the stressed site mean (0.72) minus the variance (0.22). The map shows the result of this scoring approach.

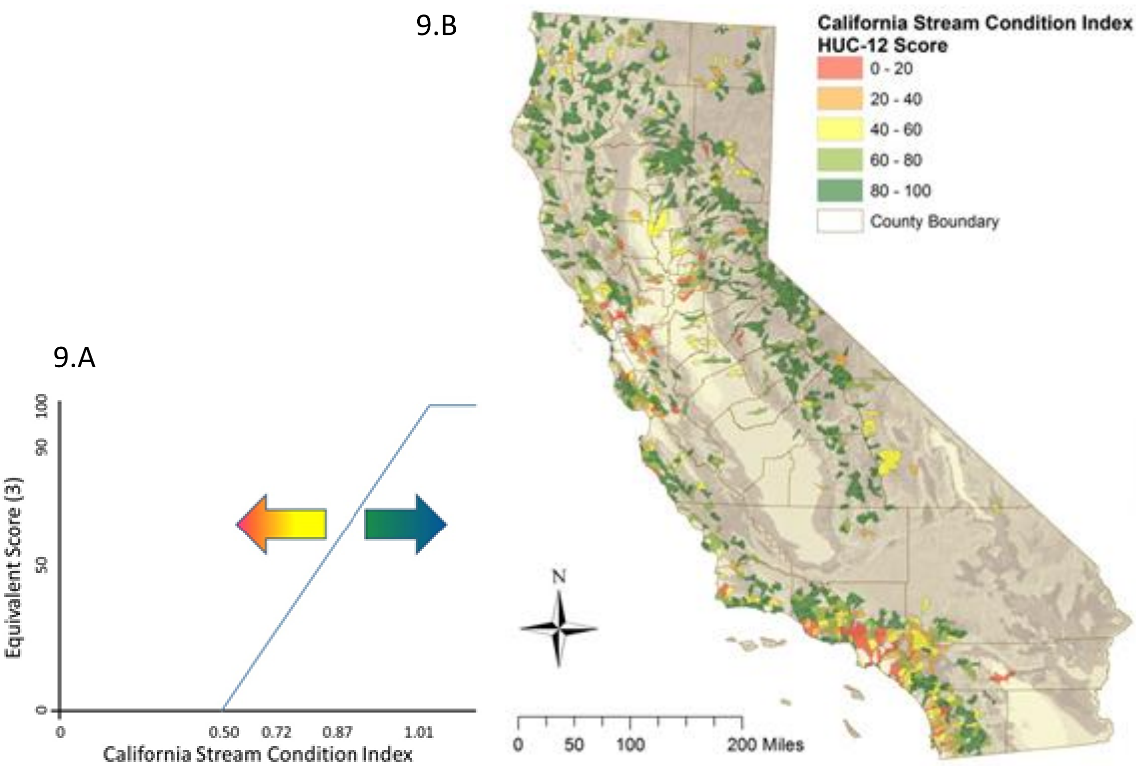


Figure 9. A) Scoring curve (Scenario 3) and B) Results (HUC 12 scale) of Scenario 3 scoring curve for California Stream Condition Index.

B. Groundwater Quality (Nitrate Concentration)

Nitrate is a primary groundwater contaminant of concern in many places in California, originating in some places from natural sources, but primarily from agricultural fertilizer use, septic/sewage systems, and confined animal feeding operations. High concentrations of nitrate in drinking water can cause "blue baby syndrome" and other health problems. The EPA and California Department of Public Health have established a maximum contaminant level (MCL) of 10 mg/L of nitrate-nitrogen, which is equivalent to 45 mg/L total nitrate. State and local agencies monitor nitrate concentrations in groundwater, water supply wells, and residential drinking water.

Three "what-if" scenarios were used. The first scenario stipulates that nitrate concentration less than or equal to the background nitrate concentration in groundwater in the Central Valley (9 mg/L; Harter et al., 2012) receive a score of 100. Nitrate concentrations greater than 45 mg/L (MCL) receive a score of 0. The second scenario stipulates that nitrate concentrations less than the MCL receive a score of 100 and concentrations >45 mg/L up to the mean of all groundwater samples in California's water supply wells in 2012 (87 mg/L; score = 0) receive scores proportional to concentration. The third scenario stipulates that a nitrate concentration of 0 mg/L receives a score of 100, concentrations above the MCL receive a score of 0, and intermediate concentrations receive proportionally intermediate scores.

Scenario 1: Nitrate concentration less than or equal to the background nitrate concentration in groundwater in the Central Valley (9 mg/L; Harter et al., 2012) receive a score of 100 (Figure 10.A). Nitrate concentrations greater than 45 mg/L (MCL) receive a score of 0. The map shows the result of this scoring approach (Figure 10.B).

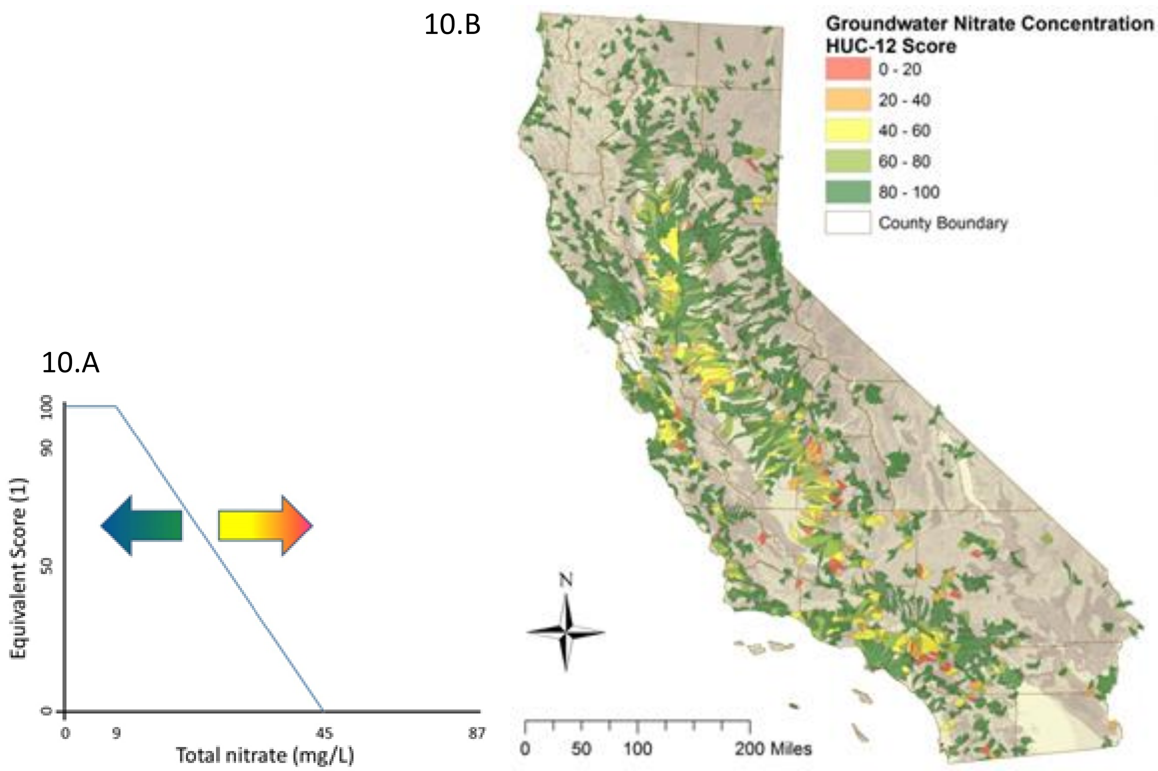


Figure 10. A) Scoring curve (Scenario 1) and B) Results (HUC 12 scale) of Scenario 1 scoring curve for groundwater nitrate concentration.

Scenario 2: Nitrate concentrations less than the MCL receive a score of 100 and concentrations >45 mg/L up to the mean of all groundwater samples in California's water supply wells in 2012 (87 mg/L; score = 0) receive scores proportional to concentration (Figure 11.A). The map shows the result of this scoring approach (Figure 11.B).

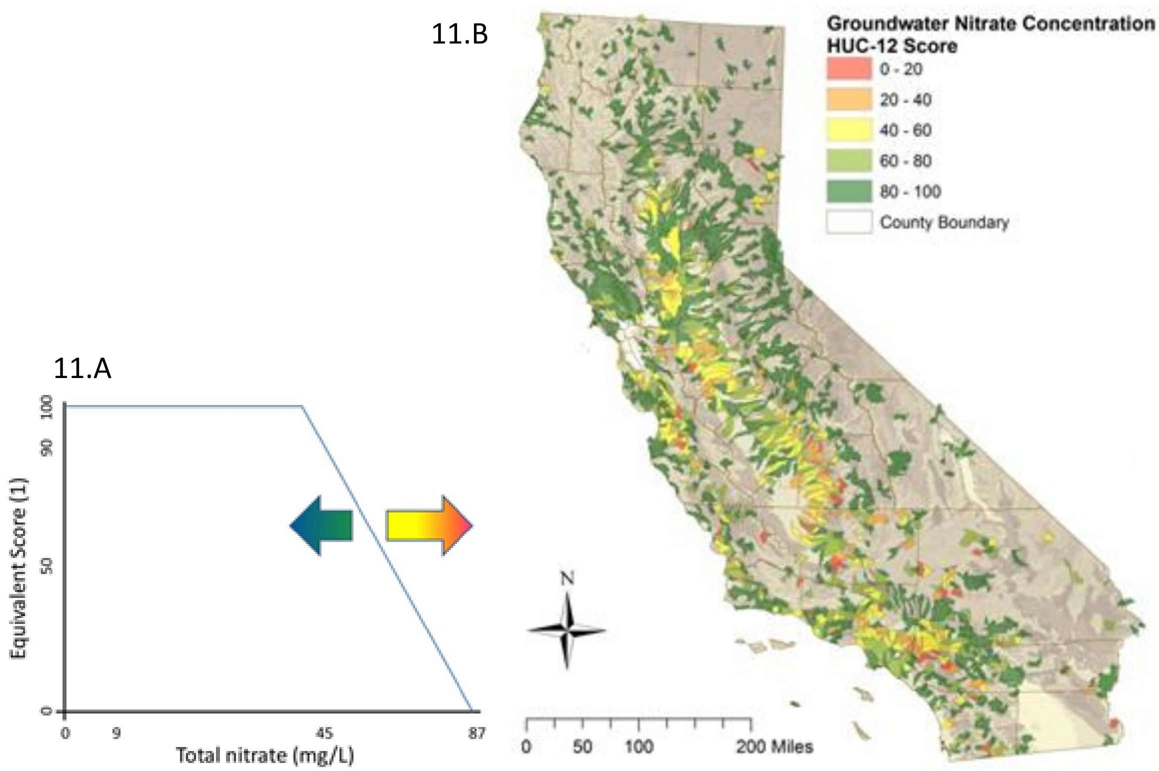


Figure 11. A) Scoring curve (Scenario 2) and B) Results (HUC 12 scale) of Scenario 2 scoring curve for groundwater nitrate concentration.

Scenario 3: Nitrate concentration of 0 mg/L gets a score of 100, concentrations above the MCL receive a score of 0, and intermediate concentrations receive proportionally intermediate scores (Figure 12.A). The map shows the result of this scoring approach (Figure 12.B).

12.B

12.A

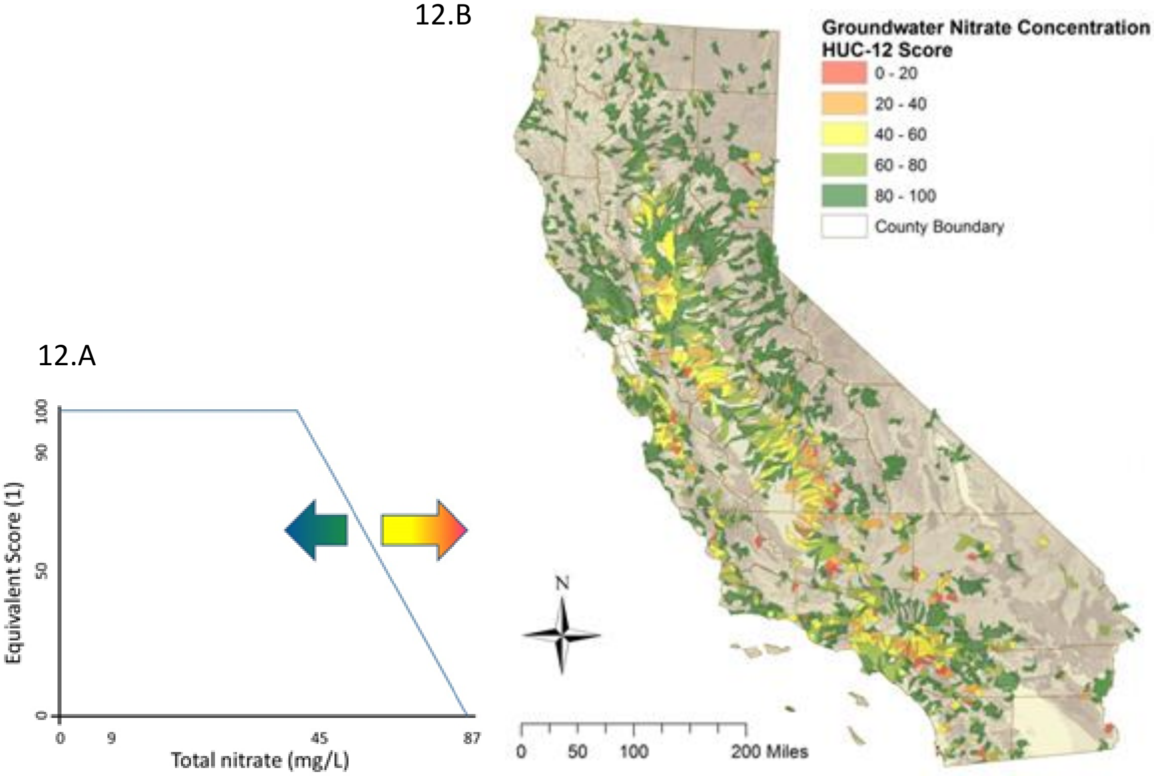


Figure 12. A) Scoring curve (Scenario 3) and B) Results (HUC 12 scale) of Scenario 3 scoring curve for groundwater nitrate concentration.

C. Water Footprint

This index measures the impact on water from production and consumption of goods and services by an individual population or region. The "footprint" is measured as volume of water consumed in goods and services in a unit time period, like one year. The water footprint has been calculated for most countries, including the United States, and as part of the current project, for California. The average footprint for someone in California is about 1,500 gal/day (Fulton et al., 2012). This is slightly less than the water footprint of the average US resident of about 1,600 gal/day (Mekonnen and Hoekstra 2011) and greater than the global average of about 750 gal/day.

Three "what-if" scenarios were used. The first scenario stipulates that the best score (100) is for a range water footprint that is determined to be in a range that is locally-sustainable ("sustainability" scenario). In this scenario, a score of 0 is equivalent to the water footprint range that is unsustainable based on current populations and precipitation patterns. The second scenario ("status-quo" scenario) stipulates that the best score (100) is for water footprints that are less than the global average and sets a score of 0 at the largest global water footprint (Bolivia, 3,500 gal/day). The third scenario ("equity" scenario) stipulates a score of 100 for water footprints at or less than the global mean and a score of 0 for water footprints at or greater than California's.

Scenario 1: Water footprint of less than or equal to a sustainable range receives a score of 100, footprints greater than unsustainable range receive a score of 0. All others between these ranges receive a proportional score (Figure 13). Sustainable ranges have not been defined for water footprints, so it is difficult to say what California's current water footprint score would be.

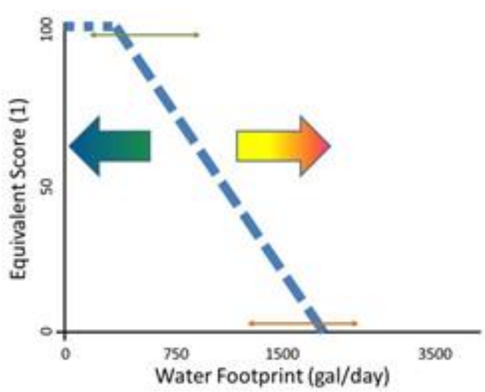


Figure 13. Scoring curve (Scenario 1) for water footprint.

Scenario 2: Water footprints greater than or equal to the greatest global value (Bolivia, 3,500 gal/day) receive a score of 0. Footprints less than or equal to the global average receive a score of 100 (Figure 14). California's current water footprint score would be about 73 under this scenario.

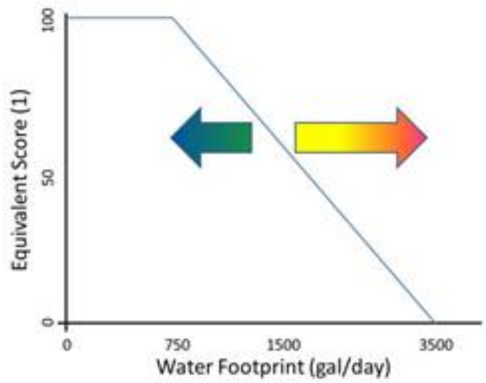


Figure 14. Scoring curve (Scenario 2) for water footprint.

Scenario 3: Water footprints greater than or equal to the value for California receive a score of 0. Footprints less than or equal to the global average receive a score of 100 (Figure 15). Under this scenario, California's current water footprint would receive a score of 0.

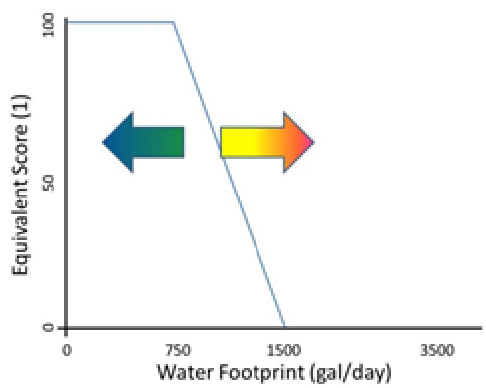


Figure 15. Scoring curve (Scenario 3) for water footprint.

4. Regional Pilot Test of the Sustainability Indicators Framework

As noted previously, in order to evaluate the utility of the Framework across the critical geographies of the state, indicators from the Framework were evaluated at the state and regional scales. In the case of the regional pilot, this was conducted in collaboration with the Santa Ana Watershed Project Authority and the Los Angeles-based Council for Watershed Health.

4.1. Selection of Indicators for Regional Pilot

The Santa Ana Watershed Project Authority (SAWPA) and Council for Watershed Health (CWH) selected water sustainability goals and objectives (Table 3) that corresponded to the One Water One Watershed (OWOW) 2.0 vision and goals. Goal and objective selection was vetted by the OWOW team and pillars (stakeholder groups).

Table 3. List of water sustainability goals and objectives for the SAWPA One Water One Watershed 2.0 plan.

Goals	Objectives
Maintain reliable and resilient water supplies and reduce dependency on imported water	Increase use of rainfall as a resource, increase use of recycled water, decrease water demand, increase water-use efficiency, sustainably develop local water resources, maintain sufficient storage to overcome multi-year (3 year) drought over a ten year hydrologic cycle, reduce green-house-gas emissions and energy consumption from water resource management.
Manage at the watershed scale for preservation and enhancement of the natural hydrology to benefit human and natural communities	Preserve and restore hydrologic function of land, preserve and restore hydrogeomorphic function of streams and water bodies, safely co-manage flood protection and water conservation, include ecosystem function in new development planning and construction
Preserve and enhance the ecosystem services provided by open space and habitat within the watershed	Increase the capacity of open space to provide recreational opportunities without degrading its quality or increasing its consumption of water & energy; protect existing and restore native habitats; manage aquatic and riparian invasive species; protect estuarine and marine near-shore habitats; reduce ornamental irrigated landscapes; improve management support for landscaping that utilizes native vegetation ; protect endangered and threatened species and species of special concern through improved habitat.
Protect beneficial uses to ensure high quality water for human and natural communities	Attain water quality standards in fresh and marine environments to meet designated beneficial uses; protect and improve source water quality; achieve and maintain salt balance in the watershed
Accomplish effective,	Improve regional integration and coordination; ensure high quality

equitable and collaborative integrated watershed management in a cost-effective manner	water for all users; balance quality of life and social, environmental and economic impacts when implementing projects; maintain quality of life; provide economically effective solutions; engage with disadvantaged communities to leverage capacity to effectively respond to their needs; engage with Native American tribes to leverage capacity to effectively respond to their needs; reduce conflict between water resources and protection of endangered species

Indicators were selected by SAWPA and CWH for the region scale that had relatively uniform data availability (Table 4) and that corresponded to the OWOW 2.0 goals and objectives. Indicator selection was vetted by the OWOW team and pillars (stakeholder groups). These indicators represent a broad cross-section of ways to evaluate water sustainability in the region, but do not capture all aspects of sustainability that individual organizations or municipalities may consider critical. The evaluated indicators could be built upon in subsequent evaluations and a picture of water sustainability for the region could begin to form.

Table 4. List of indicators for the regional pilot in the Santa Ana Watershed Project Authority service area. The corresponding SAWPA goal listed in Table 3 is shown in the far right column.

Indicator Name	**SAWPA Sustainability Goal**
Proportion of Water Use from Imported and Recycled Sources	1
Water Use (per capita)	1
Local Water Supply Reserves	1
Adoption of Sustainable Water Rates	1
Water Availability and Stress (WRI Aqueduct 2.0)	1
Annual Water Resource Energy Use Relative to Rolling Average	1
Stream Network with Natural Substrate Benthos	2
Impervious Surface: Water Quality Index and Geomorphic Condition	2,4
Coastal Impacts from Sea Level Rise	3,5
Aquatic Habitat Fragmentation	2
Open Space for Recreation	3
Invasive Species and Native Landscapes	3
Area with Restoration Projects and Conservation Agreements	3
Exceedance of Water Quality Objectives in Watershed	4
Exceedance of Groundwater Salinity Standards	4
Exceedance of Water Quality Objectives at Discharge	4
Exceedance of Water Quality Objectives at Recreation Sites	4
Biological Condition Index	3,5
OWOW (Stakeholder-Community) Participation	5

4.2. Findings for Regional Pilot

A summary of findings for the region pilot test of the Framework is presented below, while detailed results are furnished in Appendix B.

Proportion of Water Use from Imported and Recycled Water

This indicator is sensitive to the sources of water, and the use of water within the watershed. The reliability of imported water supplies is threatened by climate change, source demand, an increased awareness of environmental costs, and the expense of system operations and maintenance. Regional self-reliance is the target condition for water supplies in the Santa Ana River watershed.

Our assessment found that in 2010, 29 percent of the water used in the region is imported. Although recycled water continues to compliment supply, the prediction for the region shows that imported water supplies will account for 35 percent of water supply.

Per Capita Water Use

The Governor's Office of California issued the 20x2020 Water Conservation Plan in February 2010 that calls for a statewide reduction in water use, 20% overall by the year 2020 (California Department of Water Resources, 2010). For the South Coast Hydrologic Region, the Santa Ana River watershed, the goal is 165 gallons per capita day (gpcd) by 2015 and 149 gpcd by 2020 from the current 180 gpcd.

For residential-only, the baseline is 126 gpcd, however the 20x2020 Water Conservation Plan does not call-out residential only goals. Using the overall baseline and goals, the South Coast Hydrologic Region targets are an 8.3% reduction by 2015, and a 17.2% reduction by 2020. Using 126 gpcd as baseline, the 2015 target for residential-only in this region is 116 gpcd, and the 2020 target is 104 gpcd.

Evaluation of reports from various agencies shows that about 8.9 million people use 1.02 billion gallons per day, providing an estimate of 114 gpcd within the watershed. This value is below the baseline and the 2015 interim target for the watershed, however, is above the 2020 target.

Local Water Supply Reserves

The Santa Ana River watershed relies on imported water in a normal year, and increases that reliance during drought conditions. Regional self-reliance should include planning for reduction in imported supplies through drought conditions within the Colorado River Basin or along the Sierra Nevada Mountains. The State Water Project (SWP) and the Delta system could be crippled during an earthquake, preventing them from delivering water to southern California.

Currently the water supply within the watershed is managed properly to withstand a local multi-year drought, but it is unlikely that the area is prepared for an unexpected disruption of the SWP in an event of an earthquake in the Delta system. Nor does it seem prepared for disruptions or decreased deliveries from the SWP or the Colorado River Basin.

Adoption of Sustainable Water Rates

Sustainable Water rates encourage water use efficiency by charging increasing larger per-volume rates to high-volume users. SAWPA has committed to encouraging this management approach within its IRWM process.

The three counties that are in the SAWPA service area include Riverside, Orange and San Bernardino counties. A poll on the area's water retailers shows that over half of the 67 agencies within SAWPA use tiered rates (32 agencies).

Water Availability and Stress (Based on WRI Aqueduct 2.0)

Water stress is defined as the ratio of water withdrawals to the water available from natural and artificial sources (Reig et al., 2013). World Resources Institute (WRI) Aqueduct 2.0 project's metrics were used in our water stress assessment.

Four metrics used from Aqueduct 2.0 project are A) Available blue water, B) Baseline water stress, C) Upstream protected lands, and D) Return flow ratio. For each metric, an impact category was determined. Results from this analysis are presented in Appendix B.

Annual Water Resource Energy Use Relative to 5-year Rolling Average

The embedded energy and carbon emissions within the system of water resource provisioning and consumption have costs to the watershed. Local supplies require less power to manage, and therefore reduce carbon emissions. The target for the Santa Ana River watershed is to have an annual reduction over the five-year rolling average in greenhouse gas emissions related to the water resource provisioning system.

The five-year average (2008-2012) of CO2 equivalent emissions (million metric tons) related to water consumption was compared against 2012. It shows that there was an increase of 3.4 percent in emissions above the five-year average.

Stream Network with Natural Substrate Benthos

This indicator describes the condition of the substrate of the streams in the Santa Ana River watershed outside the National Forests. Having natural substrate (soft-bottom) permits the natural function for sediment and water flows, as well as influent and effluent conditions where groundwater and surface water flows interact. The target for the Santa Ana River watershed is to manage all streams with natural substrates. Our assessment indicates that most streams in the Santa Ana River watershed have a natural substrate.

Impervious Surface: Water Quality Index and Geomorphic Condition

Impervious surface is a measure of land cover. This indicator serves as a potential measure of impact of development on water quality and geomorphic processes.

Our analysis shows that that SAWPA has a high percentage of impervious surface cover across the watershed. From 2001 to 2006, imperviousness in SAWPA has increased an average of 0.59 percent across the region. The areas with lowest degrees of change from 2001-2006 are the least (mountains) and most (cities) densely-populated places.

Coastal Impacts from Sea Level Rise

The sea has already risen by up to 8 inches along the California coast and is projected to potentially rise another 4 to 5 feet by the year 2100 (Jevrejeva, et al., 2010; Rahmstorf, 2007; Pfeffer et al., 2008). This indicator consists of 4 primary metrics 1) extent of potential economic damage from inundation; 2) number of people affected by inundation; and 3) extent of natural system damage from inundation. Coastal impacts of sea level rise could be more than $200 billion and may displace hundreds of millions of people by 2100 if mitigation and adaptation actions are not taken (Hinkel et al., 2013).

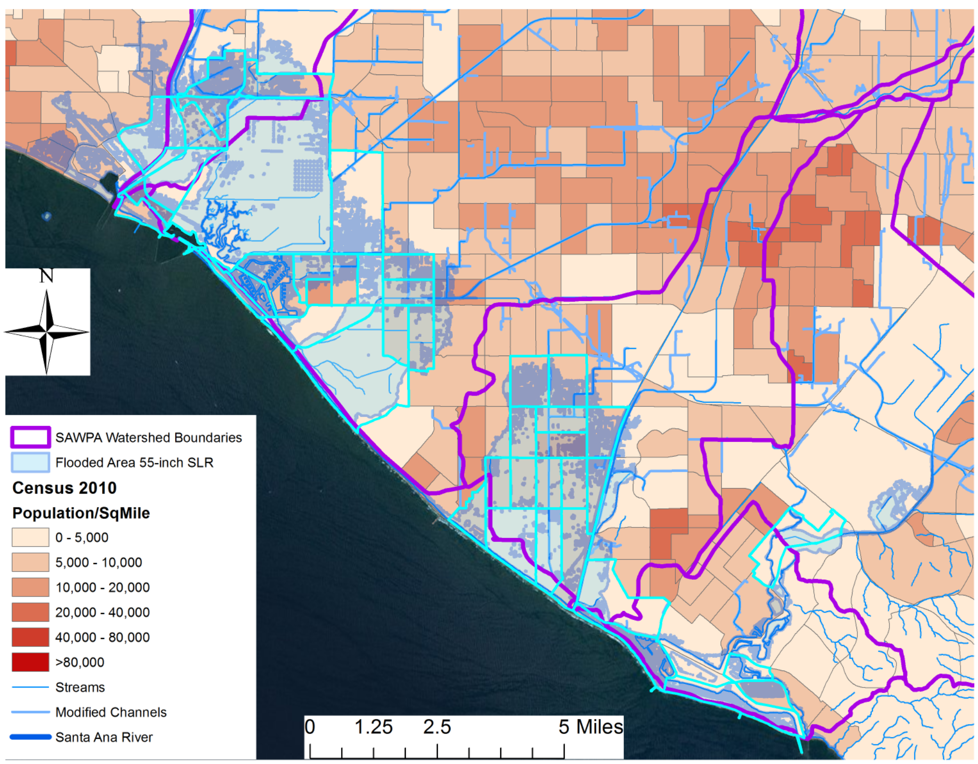


Figure 16. Potentially-inundated populated areas due to sea level rise of 1.5 m (blue areas, projected by 2100) overlaid onto Census 2010 blocks, color-coded for population density.

Results indicate that over half of the length of the coastal areas of the Santa Ana River watershed will potentially be impacted by sea level rise. Figure 16 shows the potentially-inundated populated areas with a 1.5 m sea level rise. By 2050, about 2.7 percent of the population could be affected by a 1.5 m sea level raise, with an estimated real-estate loss of $38.2 billion. The projected sea level rise also threatens to inundate about 660 hectares of coastal and estuary wetlands, a loss of 99% of those present in the SAWPA area.

Aquatic Habitat Fragmentation

Aquatic fragmentation is the potential hydrologic alteration caused by diverse type of structures, such as dams, weirs, drop structures, and other man-made systems that modify hydrologic flow. It also represents the impact of development and/or land use in the watershed.

The desired condition, from an ecological health standpoint, is that waterways in local, regional and statewide scales have a minimum or no fragmentation, so they can conserve or resemble the historical natural watershed connectivity that will allow aquatic species and systems to function correctly.

Our analysis of the 74 HUC-12 polygons in the Santa Ana River watershed shows that a little over half of them are approximately 31 percent fragmented due to road stream intersections.

Open Space for Recreation

This indicator expresses park access within the study watershed. The ideal condition is for every resident of the watershed to be within ½ mile of a park or publically accessible open space.

We find that in the Santa Ana River watershed, about 70 percent of the population has access to open space within ½ mile. Future analysis of this indicator should consider equity of distribution and ability of the open space to support the population served.

Invasive Species and Native Landscapes

This indicator describes how watershed managers are addressing challenges of invasive species. The presence of invasive species causes degradation of natural processes within the watershed.

Our analysis indicates that not enough is being done to coordinate invasive species assessment and treatment. Information about existing treatment efforts in the water is not available; a first step towards the management of invasive species in the watershed would be to compile and release this information.

Area with Restoration Projects and Conservation Agreements

This indicator measures if the open space of the watershed is being protected from development that is contrary to the goals of the watershed.

We find that the watershed area is more than a third open space, of which 69 percent is protected in some way. The area protected is mostly with the two national forests present in the watershed.

Exceedance of Water Quality Objectives in Watershed

When streams and lakes are swimmable and fishable, they provide recreational opportunities for people of the watershed.

The only report available for this evaluation, the Santa Ana Region Basin Plan, suggests that 75 percent of the streams and reaches within the watershed were in compliance in 2011 with the assessed standards. However this is not sufficient to provide water resource managers actionable guidance but does provide water quality trend information over time.

Exceedance of Salinity Standards in Groundwater

Managing the salinity of water in the groundwater basins is necessary to maintain the basin as a water supply storage location. This indicator reveals if the management of groundwater basins is properly mitigating for salts. The desired condition would be to ensure that all groundwater basins should have assimilative capacity or at least not exceed the historical ambient water quality.

Our analysis shows that 46 % of the groundwater management zones have assimilative capacity. However, the trend is negative for the remaining groundwater zones, which are heading towards further impairment.

Exceedance of Water Quality Objectives at Discharge

Anyone who discharges water into inland water bodies or the ocean is subject to regulation under the Clean Water Act. In most cases, part of the permit provided under the National Pollution Discharge Elimination System (NPDES) to each discharger requires monitoring of water quality at the "outfall", or, where the discharged waters enter the receiving waters. The data created by this monitoring is a very good source to describe how point-sources are being managed to maintain good water quality.

At the time of this report, insufficient data were available to assess this indicator. Efforts are underway to determine if water quality data from NPDES permits can be forwarded to SAWPA on a regular basis so that this indicator can be tracked in the future.

Exceedance of Quality Objectives at Recreation Sites

To provide recreational opportunities, the lakes and streams of the watershed must be clean enough to allow safe swimming. The Santa Ana Region Basin Plan requires that fecal coliform densities should not exceed 200 MPN/100 mL based on five or more samples in a 30-day period (SARWQCB 1995).

There was insufficient data to evaluate this indicator at this time.

Biological Condition Index

The composition of plant, invertebrate, and vertebrate communities living in waterbodies can reveal whether the waterbodies are in good condition, or degraded as a result of human activity. The California Stream Condition Index uses the composition of invertebrate communities in the stream benthos as a measure of stream degradation (Ode et al., 2013).

As shown in Figure 17, conditions for benthic macroinvertebrates and native fish are good in parts of the upper watershed and just upstream of Prado dam and generally poor in developed areas.

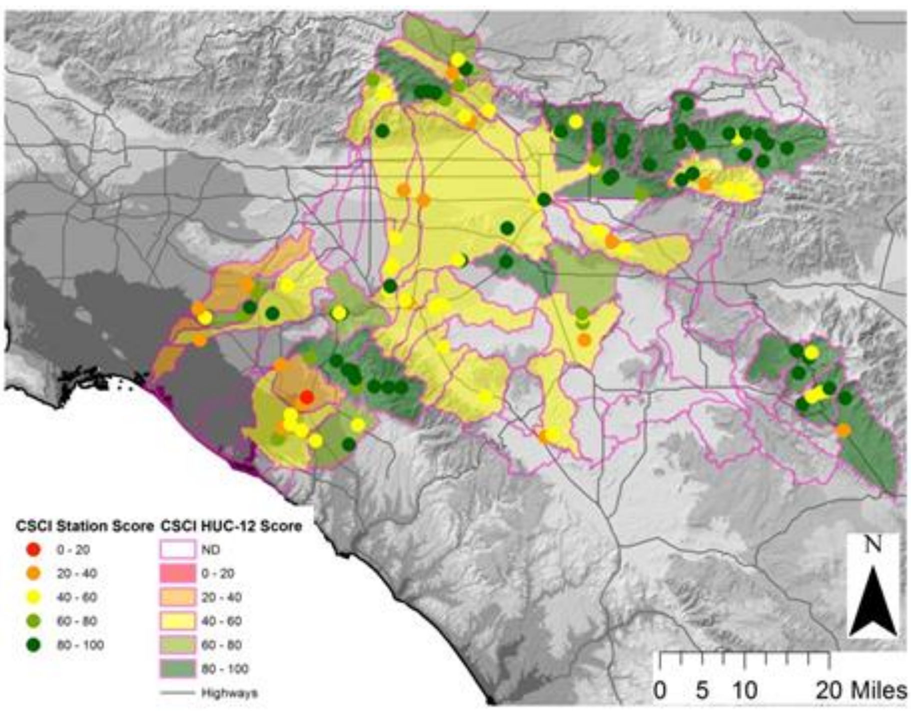


Figure 17. Biological indicator score for California Stream Condition Index for individual streams where benthic macroinvertebrates were sampled and the corresponding HUC-12 watershed

OWOW Participation

This indicator seeks to understand if the goal of having all stakeholders represented in the watershed management effort is being met. This indicator was not assessed as the data necessary is not currently being created or maintained. We suggest that the data must include a measure of participants in the process and their connection to the communities of the watershed.

Performance of OWOW 1.0 Selected Projects

This indicator looks at the required monitoring of OWOW projects to assess if the projects, as a group, are performing as was expected when they were selected for funding. The target is that the performance of projects selected by the OWOW process properly aligns with the stated outcomes, and that the goals of the OWOW process are slowly achieved through integrated management. However this indicator was not evaluated because of lack of a sufficient data set.

The full assessment of the indicators, definitions, data considerations and assessment methods are provided in Appendix B.

5. Web-Based Decision Support Tool for Sharing Sustainability Indicator Information

A critical feature of improving sustainability is learning about the status of water, air, land, or societal resources at a given time and developing management tools or other strategies and actions that can improve the status of a resource if it is not being managed sustainability. The internet has expanded our ability to disseminate information; to this end we created the Water Sustainability Indicators Framework web site http://indicators.ucdavis.edu (Figure 18). This web-based Decision Support Tool allows us to share information about specific indicators, findings from evaluating the indicators, and a catalog of many indicators that others have used around the world to measure various aspects of sustainability.

Figure 18. Front page of the sustainability indicators framework website (http://indicators.ucdavis.edu)

The website is organized around the principle and goal of sharing information to support decision-making. This is accomplished in three main ways: 1) sharing information about indicators in the global Catalog (Figure 19) and in the list of recommended indicators for the California Water Plan so that users can decide for themselves what constitutes a reasonable indicator or set of indicators for their need; 2) sharing results of the evaluation of specific sustainability indicators and indices at the California scale as examples of how indicators can be used and reported; and 3) sharing indicator scores at various scales, from hydrologic regions to smaller watershed scale, to give users a sense of conditions across scales for certain indicators.

The website was not designed to guide specific water-related decisions (e.g., rate of water delivery at a specific facility) so much as to show the kind of information that could be provided to educate the public and stakeholders about water conditions and management and eventually to provide detailed, geographically focused information that could be cited as supporting specific decisions.

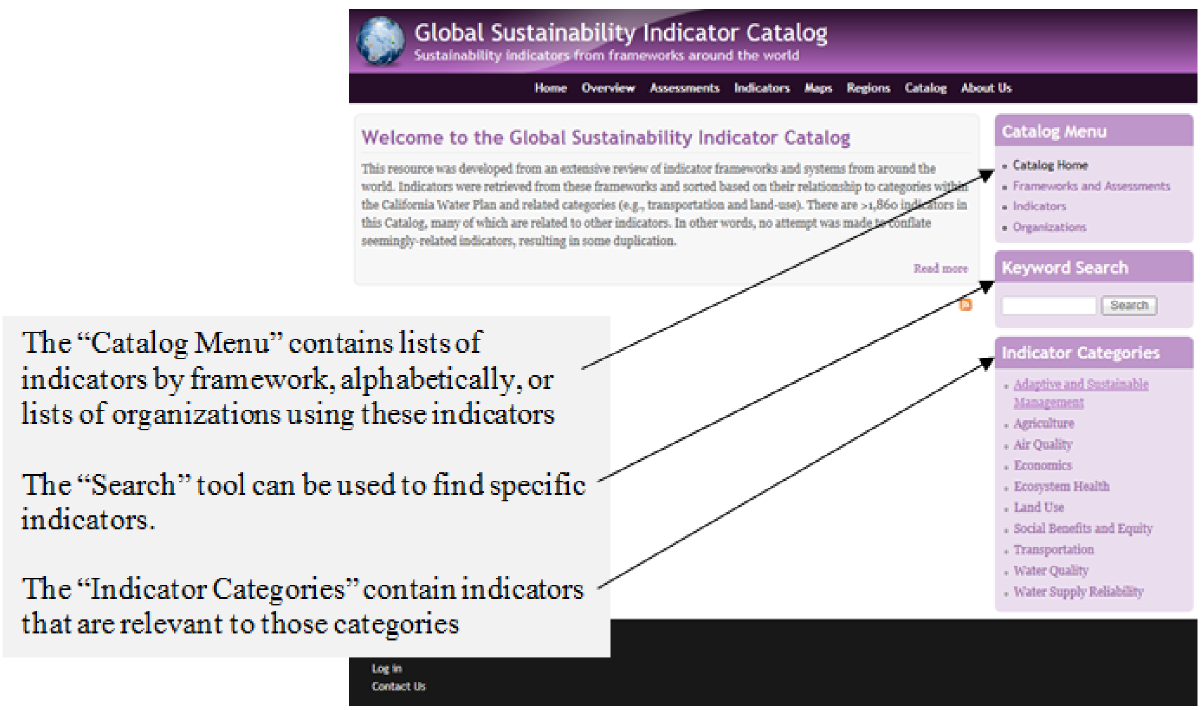


Figure 19. Catalog of sustainability indicators drawn from frameworks around the world

The website includes a mapping tool that can show the results of an evaluation of indicators (Figure 20). Users can change the base layer map across geographic scales (e.g., hydrologic region to HUC-12 sub-watershed). They can also select the results of indicator evaluation at different scales: hydrologic region (HR), river basin Hydrologic Unit Code (HUC-8), sub-basin

(HUC-10), or sub-watershed (HUC-12). Beneath this mapping tool, the user can also access downloadable forms of the data for each mapped indicator.

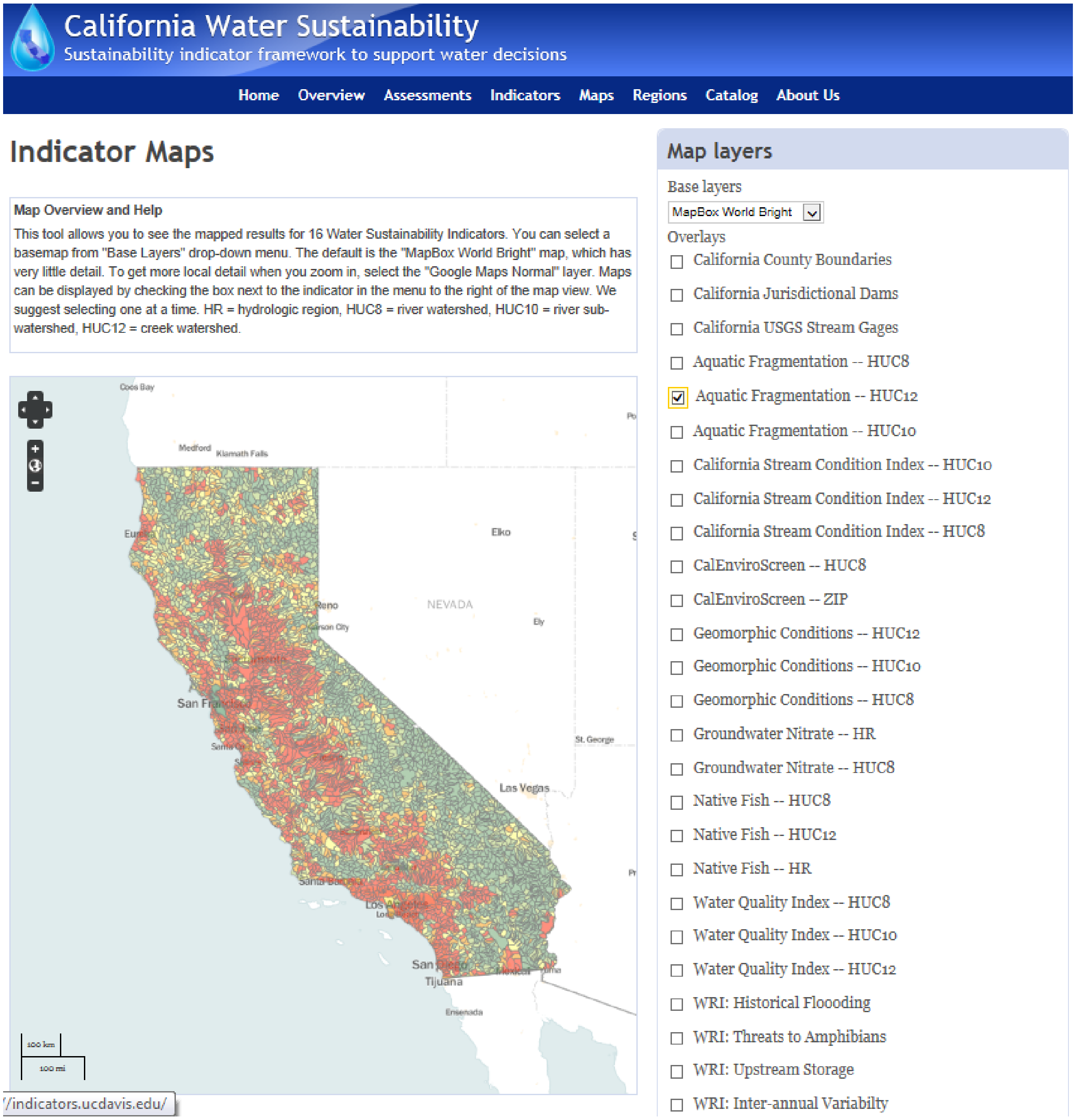


Figure 20. Mapping tool to display the results of evaluating specific California Water plan indicators

Users can also use the "Water Plan Indicators" icon on the front page, to access web pages that describe the specific indicators (What is it? Why is it important? etc.) and dynamically view the mapped results of evaluating them at the state scale (Figure 21). The user can also view JPEGs of mapped results of indicator evaluation (Indicator Results) and download the data for a specific indicator (Data Resources).

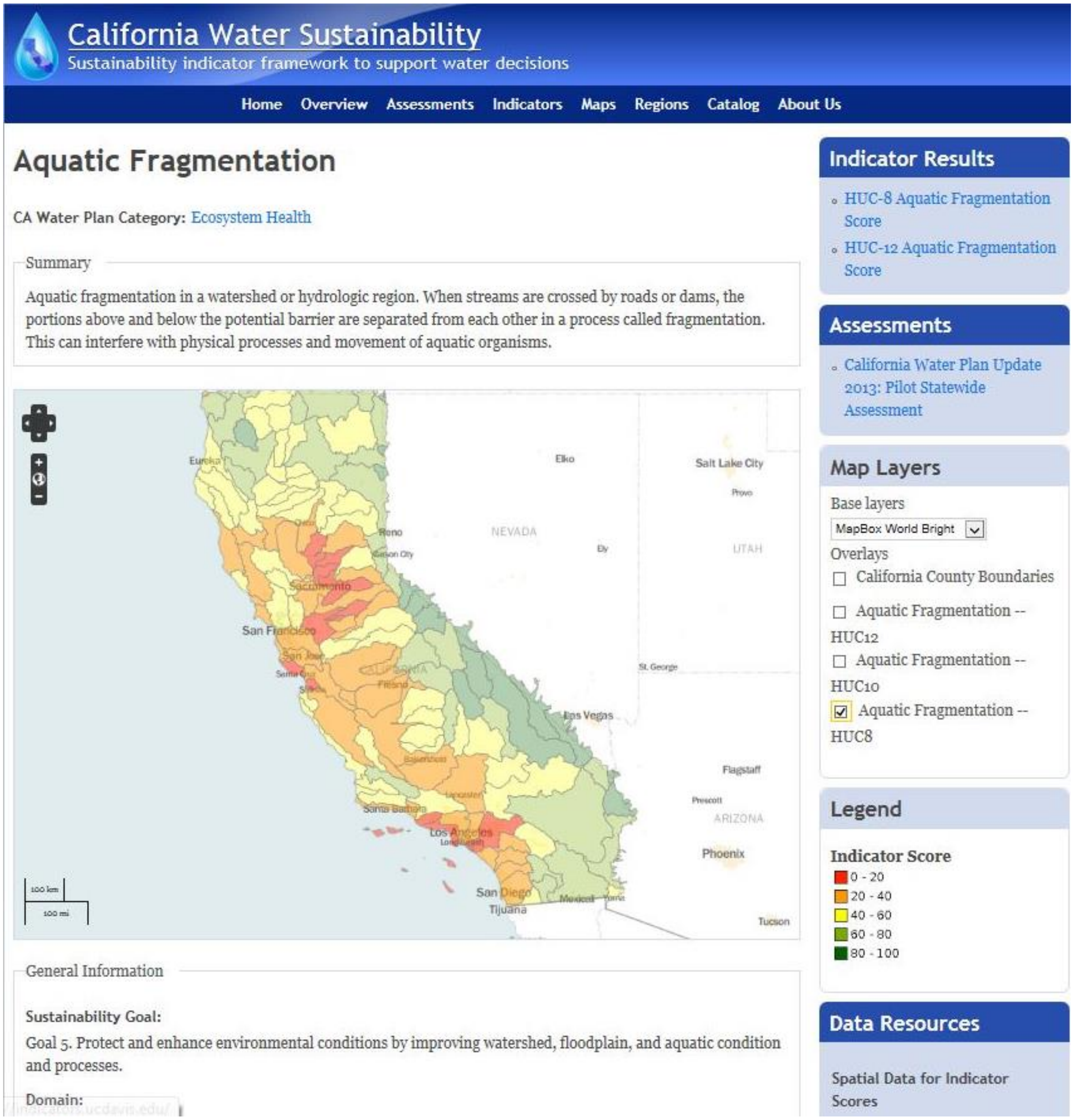


Figure 21. Example web page for one of the indicators evaluated at the state scale

6. Lessons Learned and Data and Information Gaps

This section describes the lessons, issues, and data gaps that arose during the more than 2-year process of developing the sustainability indicators framework and its application at the state and regional scale pilots. These are preliminary observations resulting from the overall process.

6.1. Stakeholder-Inclusion

The Sustainability Indicators Framework was tested at the state and region scale. The region chosen was the Santa Ana Watershed Project Authority (SAWPA) service area. At that scale, SAWPA was responsible for interacting and including stakeholders in the development of the indicator system used in that region. SAWPA was coincidentally developing its One Watershed One Water (OWOW) 2.0 plan and indicator development was rolled into that process. The OWOW process includes stakeholders in structured venues called "pillars," which are interest areas (e.g., water supply) that people voluntarily join, such as the "Government Alliance Pillar." SAWPA reports in their OWOW 2.0 draft plan that 4,000 diverse stakeholders regularly receive information about OWOW, including interested members of the public, Tribes, businesses, non-governmental organizations, representatives of 120 public agencies and elected officials and staff from 63 incorporated cities and the 4 counties that compose SAWPA (Los Angeles, Orange, Riverside, and San Bernadino). SAWPA communicates about OWOW using email, social media/networking tools, stakeholder presentations, workshops, and conferences. As SAWPA states, this level of engagement is at the high-end of effort in California for regional water planning and management.

Issue: Despite this level of stakeholder involvement, it was apparent after discussion with knowledgeable individuals that disadvantaged communities (DAC) still face barriers that prevent them from participating in the planning process. A consultant for SAWPA has worked for several years to improve outreach and in-reach between DACs and the OWOW process. Given that there are over one million DAC members in the SAWPA area, the rate of interaction may still be too low to be able to measure success of DAC inclusion in the OWOW process. The assumption here is that because many DACs have expressed that their interests are not always represented by elected officials; other means must be used besides inclusion of city and county staff and officials. That being said, SAWPA still is one of the most inclusive IRWM regions, or water authorities at including DACs in their planning process. However, the scale of effort of SAWPA, as well as other similar entities in the state, may need to be dramatically increased in order to make sure DACs are included in planning that affects them.

Solution: At the regional scale, it is important to scale outreach and in-reach effort to match the size of the populations. This does not mean that everyone in a service area needs to be involved for the process to be regarded as successful, but everyone, or their chosen representative, needs to have the opportunity to participate in a meaningful way. This will allow them to understand the process and provide feedback.

At the state scale, two main engagement processes were used to involve stakeholders in indicator system development. The first was the advisory committee structure of the Water Plan Update. The Public Advisory Committee and Tribal Advisory Committee were asked to review and provide feedback on the sustainability indicator framework and its component indicators. This was done during the design of the Framework and at interim steps when some indicator evaluation work had been completed. The second engagement process was with the inter-agency steering committee, which includes the over two-dozen agencies that collaborate on the Water Plan and advises DWR on development of the Water Plan Update. Several presentations were made to this group and written and verbal feedback sought.

Issue: Given the size and complexity of the state, this level of stakeholder inclusion may be insufficient for something as important as development of indicators to describe sustainability. California has many diverse communities with very different priorities, lifestyles, cultural practices, resource-availability, and understanding of how natural and artificial water systems work. For an indicator and reporting system to be effective in the stated goal of affecting knowledge and decisions, people and institutions need to feel like they understand it and can influence its development.

Solution: The Water Plan process has two existing processes that could provide venues for improved stakeholder inclusion in indicator system deployment. One is the existing, or expanded range of advisory committees, the other is the Regional Forums, which are extended and structured conversations between regional stakeholders and the Water Plan team. Another system that could be used to passively engage people is an online reporting system displaying periodic scores for water conditions, especially if that system had a feedback mechanism.

6.2. Indicator Selection and Evaluation

A rigorous and transparent process was used to select indicators at the state and regional scale. At the state scale, a set of indicators were proposed as part of the draft Sustainability Indicators Framework. These were selected from a combination of global indicator frameworks and existing frameworks in California. The proposed indicators were reviewed in the stakeholder process (described above), leading to minor revisions in the indicator list. Evaluation of indicators was carried out by UC Davis staff using scientific literature as the primary guidance on how to evaluate individual indicators. In the SAWPA region, the stakeholder groups were active in selecting and reviewing selections made by the team of UC Davis, SAWPA and the Council for Watershed Health. Most of the indicators selected were directly related to water supply and quality. SAWPA was very active in both deciding how indicators would be evaluated and conducting a sub-set of the evaluations.

Issues: Although many people were given a chance to provide feedback on indicators for the Water Plan, there was limited feedback from the stakeholders. This may result in less buy-in from stakeholders who either do not understand or do not relate to indicators that are described as important in measuring sustainability. For the SAWPA region, this was less of a problem, with sophisticated and informed input from SAWPA staff and certain agency stakeholders. There did not seem to be much input from stakeholders on the indicators, but they may not have had much exposure to the indicators. The inclusion of sustainability indicators in the OWOW 2.0 may prompt more feedback for the next OWOW.

Solutions: At the state scale, it will be important to educate stakeholders trusted to be representatives of certain interests and geographic areas and engage them more actively in selecting and evaluating indicators. That being said, it will also be important to keep some consistency in the set of indicators used so that trends over time can be meaningfully assessed.

6.3. Information Sharing

The Water Plan process depends on both active and passive engagement of stakeholders in the content and implementation of the Water Plan. Active engagement involves the Water Plan staff going to each region and holding workshops and meetings about the Water Plan Update. In addition, facilitated Public and Tribal Advisory Committees provide the perspectives of broad ranges of political and scientific entities and interests. The development of the sustainability indicators framework was made transparent in these venues to encourage feedback. In addition, a website was developed that contained the catalog of global indicators, the proposed Water Plan indicators, the mapped results of the indicator evaluations at the state scale, a data store, and explanations of how indicators were evaluated.

Issues: As discussed above, stakeholder participation and feedback was limited compared to the desired level of input for a state as large and complex as California. In addition, although indicator information was passively and actively shared with potentially interested parties, there was no evaluation of the information sharing process to determine whether or not it was effective.

Solutions: It would be useful to develop a strategy for two-way communication with a greater assortment of stakeholders. Accomplishing this could start with consulting stakeholders about what makes a good process for technical information sharing between them and the indicator evaluation team. A website may be a good tool to share large amount of technical information, as long as it provides what people expect, in a way they expect it and it is easily understandable. Given the wide range of ways that people understand information, it is possible that more than one way of sharing the information will be needed.

6.4. Knowledge, Information and Data Gaps

Indicator selection often includes implicit or explicit consideration of data availability. In the case of the Sustainability Indicators Framework, data availability was one of the factors used in selecting indicators. That being said, it was not a required factor, meaning that an indicator that was otherwise appropriate, but that lacked current data could still be selected. There was considerable variation in the spatial and temporal coverage of data for individual indicators. For example, there is fairly high-resolution land-cover data for California, but the methods for classifying land cover types has changed over time, making trends analysis challenging. The following list includes many of the gaps in knowledge and data that affected use of specific indicators.

Data Gaps:

1. Lack of data for portions of water cycle. The paucity of gaging stations in California means that high-resolution analysis and modeling of flows and hydrology in streams and rivers is not always possible. In addition the lack of up-to-date online information about withdrawals from ground and surface water sources for human use means that it can be years before an assessment of hydrologic condition is possible.
2. Lack of central organization of data.
3. Lack of consistency among agencies for delivery of similar data.
4. Lack of geographic coverage for aquatic ecosystem conditions.
5. Lack of regular monitoring of water quality, aquatic biota, and human use of aquatic ecosystems.

Knowledge and Information Gaps:

6. What is sustainability? A key component of the sustainability indicator framework project has been a discussion of terminology. Although the team (UC Davis, DWR, and USEPA) developed consistent use of terms, there was considerable discussion about what constitutes “sustainable.” There was also considerable discomfort with the idea that we currently may not be sustainable in our water use and management, with developing or sharing results of indicator evaluation that showed poor performance, and with making any links between measurably or potentially unsustainable practices and the lifestyles and economic activities that led or could lead to failure to perform sustainably. Given the importance of becoming sustainable in terms of water (and many other things), it would be useful to broaden the discussion of defining and measuring sustainability and describing the link between defining and measuring sustainability and acting sustainably.
7. Measuring sustainability with uncertainty. A predictable characteristic of water and environmental data analysis, modeling, and assessment is the presence of considerable uncertainty and variation from multiple sources, including measurement error and natural variation. Usually, uncertainty in estimating current and past conditions can be reduced

with more measurement. Knowledge of existing uncertainty associated with condition assessment may be used as part of resource management. However, if climate change causes unpredictable and variable changes in local and regional climatic conditions (e.g., timing and intensity of precipitation), then this new source of natural variation may overwhelm attempts to manage conditions toward a sustainable range.

8. Making decisions about sustainability with partial information. It is likely that most assessments of sustainability and decisions about sustainability will be based upon partial or imperfect information. There are formal mechanisms to deal with imperfect and partial information, including decision-making under uncertainty and computer models driven by knowledge networks and other logical frameworks (e.g., Ecosystem Management Decision-Support).
9. Role of virtual and managed water in managing water sustainability – “one water” is a useful meme to capture the idea that California’s economic activities and environmental conditions operate in a single, yet intricate global water and trade cycle. This ecology of water is barely recognized in planning, yet is one of the most important forces currently in rate of water extraction, use and flows in California’s streams, pipes, and consumption pathways.
10. Ecological, social, and economic condition assessment under water sustainability. Using indicators to measure sustainability is not the same as using predictive or retrospective models of relationships and causation. At the same time, taking many measurements of the health of corporal sustainability can tell us how we are doing in a way that can be reported to the many in society that rely on and cause changes in relative sustainability. It would be useful to establish close links between the science of modeling economic, social, and ecological condition and the science of evaluating sustainability across these domains.

7. Next Steps

The following is a synopsis of areas of research that could be conducted for the 2018 Water Plan Update.

1. An integrated system is needed that addresses water sustainability from both the perspective of quantifying conditions indicative of sustainability and measuring/reporting performance in achieving sustainability through management actions. For ease of explaining the system to stakeholders, this system could consist of a series of self-contained indices (e.g., water quality index) that report to the Water Plan sustainability goals. The approximate 120 indicators suggested in the Water Plan Update 2013 and the 19 evaluated represent a start. The next step is to go beyond the pilot and establish a core set of indicators that is used annually and in subsequent Water Plan Updates. This would ideally include the Water Footprint (see below) as a critical tool for measuring California's current and future sustainability.
2. Regions are an important scale for stakeholder process and planning in California. The sustainability indicators framework and the water footprint were not discussed in detail in regional forums for the 2013 Water Plan. The pilot region, SAWPA, embraced the framework, as evidenced in its permeation throughout SAWPA's OWOW 2.0 process. Using SAWPA's experience as a tool in communicating with other regions about measuring water sustainability will inform our outreach efforts with other regions. We suggest that a more structured stakeholder engagement will help establish indicators, performance measures, and indices like Water Footprint in the corporate understanding of how to measure and act on water sustainability. This could be a two-way discussion where regional stakeholders share what they think are important indicators/measures to report on sustainability in their region. The result would be improved buy-in by regions into a structured sustainability assessment system.
3. The sustainability reporting system would ideally have an online presence, which meets the public's and decision-maker's expectation that information is available through portals. It is likely that California will continue to have multiple systems online for reporting water conditions. At a meeting among DWR, UC Davis, and SWRCB staff, it was agreed that by ensuring transparency of datasets and web protocols to web engines, multiple systems could still have a virtual seamlessness. UC Davis has designed many of the state's environmental informatics systems, including for SWRCB and DPH. We propose to support the online reporting of water sustainability in a way that appears integrated with other information portals (e.g., MyWaterQuality) so as to support stakeholder expectations and reduce apparent duplication of information online.
4. Continued quantification of indicator condition from Update 2013 will build confidence in the indicator system. It usually damages indicator systems' utility if indicators are changed every evaluation cycle. Also, trends in condition are useful both in understanding rates and directions of change for critical components of the water system,

as well as in prioritizing action and resources. We propose that a core set of indicators/performance measures from the Update 2013 be evaluated for at least the 2013-2018 interval and preferably for earlier time periods.

5. There was an initial inclusion of coastal and climate change-related indicators in the Sustainability Indicators Framework. These included coastal impacts (economic, infrastructural) of sea level rise and ecological health in coastal ecosystems. We propose a more thorough evaluation of the role that coastal ecosystem indicators and indicators of coastal change from climate change could play in the Water Plan. This could include a closer nexus between the water supply/quality focus of the Water Plan and coastal processes. For example, coastal aquifers, water treatment plants, and estuarine ecosystems are all likely to be negatively affected by sea level rise. Quantifying threats and their significance to water planning will help integrate coastal processes into the Water Plan Update 2018. It will also help to establish the boundaries of concern for the Water Plan's inclusion of the coast as an important part of planning.
6. Initial work on California's Water Footprint raised several questions about the water-related risks entailed in California's Water Footprint and its increasing externalization. This understanding needs to be further improved and its relevance better articulated to California water planning through the following key research questions:
   a) How is California's water footprint expected to change over the next 30 years, quantitatively and geographically? What are the drivers of those changes?
   b) How does California's current and projected internal and external Water Footprint relate to water scarcity, water quality, and other related risk factors?
   c) How do agricultural patterns (e.g., crop types per region) affect the footprint of production and how could this knowledge inform choices by farmers?
   d) How is climate change likely to affect California's Water Footprint?
   e) What are the ranges of uncertainty in Water Footprint projections and analysis?
   f) What could a sustainable California Water Footprint look like for a population of 50 million by mid-century? Is self-sufficiency possible? Is food security feasible?
   g) What are the available management and policy tools to embed the California's Water Footprint in decision-making?
   h) How will regional population and economic growth within California affect how water footprints are distributed among California's hydrologic regions and river basins?
   i) How could in-state water allocation be optimized for different goals, such as food security, regional self-sufficiency, or economic productivity?
   j) How will anticipated (and uncertain) global changes in the water cycle affect California's import and export of virtual water in agricultural products?

8. Citations

Fulton, J., H. Cooley, and P.H. Gleick. 2012. California's Water Footprint. Report of the Pacific Institute. Pp. 53.

Mekonnen, MM, and AY Hoekstra. 2011. National Water Footprint Accounts: The Green, Blue and Grey Water Footprint of Production and Consumption, Value of Water Research Report Series No. 50.

Additional citations from various sections are furnished in Appendices A and B.

Appendix A. State-Scale Test of the California Water Sustainability Indicators Framework

The following pages provide the results of the pilot test of the Framework at the state scale. The indicator evaluations are in the order shown in the table below. For each indicator, there is a description of the indicator, why it is important, the findings for California and brief description of how the indicator was scored.

Indicator Name
1. Aquatic Fragmentation
2. California Stream Condition Index
3. Geomorphic Condition
4. Groundwater Quality (Nitrate & Other Contaminants and Threats)
5. Native Fish Species
6. Public Perceptions of Water
7. Water Footprint
8. Water Quality Index
9. Water Use and Availability
Indicators from the Aqueduct 2.0 Project (World Resources Institute):
10. Baseline Water Stress
11. Groundwater Stress
12. Historical Drought Severity
13. Historical Flooding
14. Interannual Variability
15. Seasonal Variability
16. Return Flow Ratio
17. Threats to Amphibians
18. Upstream Protected Lands
19. Upstream Storage Ratio

1. Aquatic Fragmentation

The breaking up of stream and river habitat continuity by artificial structures, likes dams and roads.

Sustainability Goal:

Goal 5. Protect and enhance environmental conditions by improving watershed, floodplain, and aquatic condition and processes.

Sustainability Domain:

Ecosystem Health = The condition of natural system, including terrestrial systems interacting with aquatic systems through runoff pathways.

What is it?

Aquatic fragmentation is the potential hydrologic alteration caused by diverse type of structures, such as dams, weirs, drop structures, and other man-made systems that modify hydrologic flow.

It is an influence indicator that is directly or indirectly connected to effects on aquatic habitat functioning and species condition. It also represents the impact of development and/or land use in the watershed. The effects of structures are not limited to roads. Other disturbance features, such as seismic lines, pipelines, and rail lines, have been shown to have both direct (increased mortality) and indirect (avoidance of high quality habitat) effects.

The aquatic fragmentation indicator identifies the proportion of the watershed or stream segments unfragmented by dams and road crossings of streams. A complementary metric is the density of road/stream intersections within a watershed area.

Why is it Important?

Streams and rivers may be disconnected by physical and other barriers. Dams, culverts, in-stream impoundments, high temperature, and excessive aquatic plant growth can all separate waterways into segments (Bourne et al 2011). Fragmentation caused by these natural or artificial barriers cause different effects in watershed health and wildlife that depend on it.

Changes in physical, geomorphological and chemical properties of watersheds are one type of aquatic fragmentation impacts. Natural processes are also altered by the physical and structural changes in watershed and consequently, aquatic organisms and their life cycles are also impacted. Locations where roads cross waterways change the natural shape of the river and how it is allowed to flow through the barrier. This can increase sediment transport and deposition and erosion in riparian habitats (Warren and Pardew 1998, Forman and Alexander 1998). Increases in sedimentation lead to changes in flow regime and water stability, stream channel instability, and reduced water quality (Rieman and McIntyre 1993). An increase in fine sediments, particularly in small spawning streams, can have negative impacts on fish egg survival and spawning success and may directly kill aquatic organisms (Newcombe and Jensen 1996).

Aquatic fragmentation has direct and indirect effects on the ecology, diversity and abundance of a variety of aquatic organisms. Andrew and Wulder (2011), for instance, analyzed the relationships between the population trends of Pacific salmon, from 1953 to 2006, and land cover, fragmentation, and forest age. Their results showed that effects are species specific, but characteristics indicating a legacy of historic and current forest management generally had negative effects, driven by a small subset of highly fragmented watersheds. In particular, the results showed that chum and coho salmon had strong negative relationships with fragmentation. Bain and Wine (2010) studied watershed in the Hudson River and found out that large stream fragments support higher species diversity, more abundant populations, and a greater range of fish sizes.

In addition, the movement and migration of aquatic species is altered due to aquatic fragmentation. Crossings and higher barrier frequency could be associated with increases in the water velocity due to the configuration of a road crossing and are inversely proportional to fish movement (Warren and Pardew 1998). Raymond (1979) and Fergusson et al (2006) have documented that turbines and dams have adverse effects on survival and migration of juvenile salmon, mainly chinook and steelhead, in the Columbia River system.

Roads can also increase the risk of overharvesting for many game fish species (i.e. lake trout and bull trout); for example, road densities as low as 0.1km/km2 have been found to negatively influence trout populations, and new road access into previously remote aquatic habitats can increase angling and poaching mortalities (BCMWLAP 2002).

In summary, whole watershed connectivity is critical for effective conservation of rivers and networks of wetlands to ensure natural processes (Moilanen et al. 2009; Nel et al. 2009); including upstream connectivity, maintenance of biological diversity, fish migratory routes, free-flowing rivers, significant water yield areas and water quality.

What is the target or desired condition?

The desired condition, from an ecological health standpoint, is that waterways in local, regional and statewide scales have a minimum or no fragmentation, so they can conserve or resemble the historical natural watershed connectivity that will allow aquatic species and systems to function correctly. The target condition is that 100% of the watershed is unfragmented and the density of road/stream intersections and dams is 0 crossings/km^2, representing a score of 100. The corresponding undesired condition or target is a density of fragmenting elements that blocks natural movement of aquatic organisms. After review of the literature on road-stream crossings, Fiera (2012) used a value of 0.6 crossings/km^2 to represent a “high pressure” on aquatic biodiversity; which is the value used here to represent a score of 0. A qualification on this approach is that if roads intersect streams via a bridge or causeway that spans the floodplain, then the fragmenting effect of the road may be minimal or nil. Therefore, a modification of the desired condition target is that all road-stream intersections are composed of crossing structures that either span the floodplain or demonstrably do not inhibit functional connectivity of upstream and downstream areas.

What can influence or stress condition?

The desired condition of an unfragmented watershed system can be influenced by any type of structure or barrier that disconnect or limit the natural flow of the waterway and will affect directly or indirectly its biological and physical features. Large and small barriers should be considered when evaluating riparian conservation efforts considering that both types of structures have effects on wildlife (Tiemann et al 2004) in the watershed.

Basis of calculation and use

The proposed scoring system for aquatic fragmentation comes from two distinct methods. The first involves a percentage of the HUC 12 (2012) watershed that is “unfragmented”, that is, above a disturbance site. In this analysis, the Passage Assessment Data (PAD) (2013) is used to demarcate new watersheds, referred to here as “PAD watersheds”. All watersheds created by the PAD data points represent areas of the HUC 12 that are separated from the rest of the HUC 12 watershed downstream. In some cases these PAD watersheds are much smaller than the HUC 12 watersheds; in others they are much larger. An additional measure is also used, the density of road/ stream intersections within each HUC 12 watershed in a standardized per unit length of stream as determined by the National Hydrography Dataset (NHD) (2013), or density per unit watershed area. These two methods are combined to create a scoring system by which each HUC 12 watershed within the area of interest is ranked.

What did we find out/How are we doing?

Because of the high density of roads in the state, about half of the state received a score in the lowest category of 0 – 20 (Figure 1). This effect was concentrated in the urban areas of the San Francisco Bay Area, Southern California, and Sacramento. However, there were also sub-watersheds that had low scores due to rural housing development (e.g., Sierra Nevada foothills) and forest roads developed for agriculture (.g., Central Valley), logging (e.g., North Coast) and ranching (Sierra Nevada foothills) (Figure 1). The extensive spread of low scores for aquatic fragmentation means that there are few unfragmented areas in the state, with the desert regions having the least fragmentation.

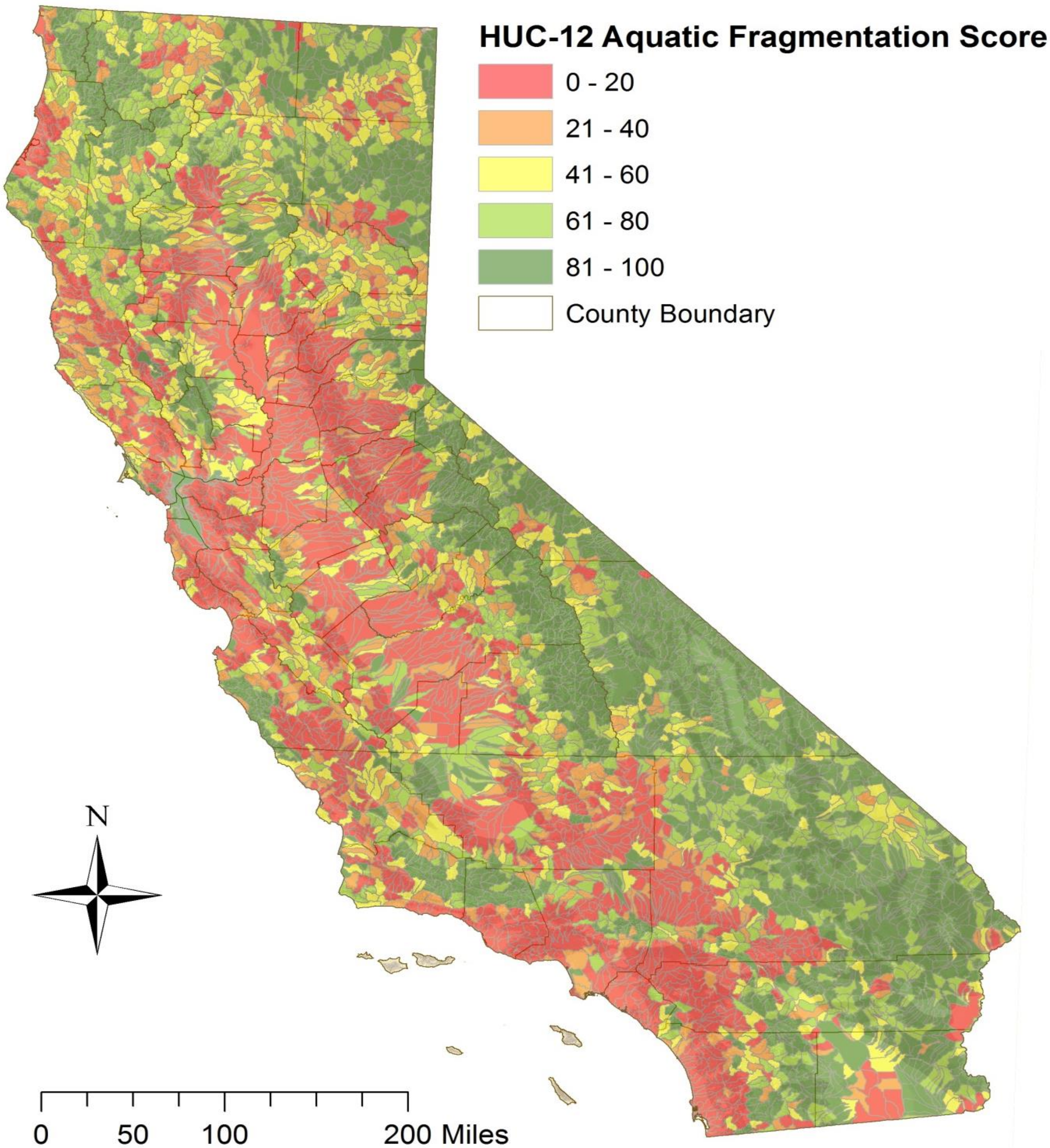


Figure 1. Aquatic fragmentation scores for HUC 12 watersheds. Fragmentation in this case is represented by road-stream crossings.

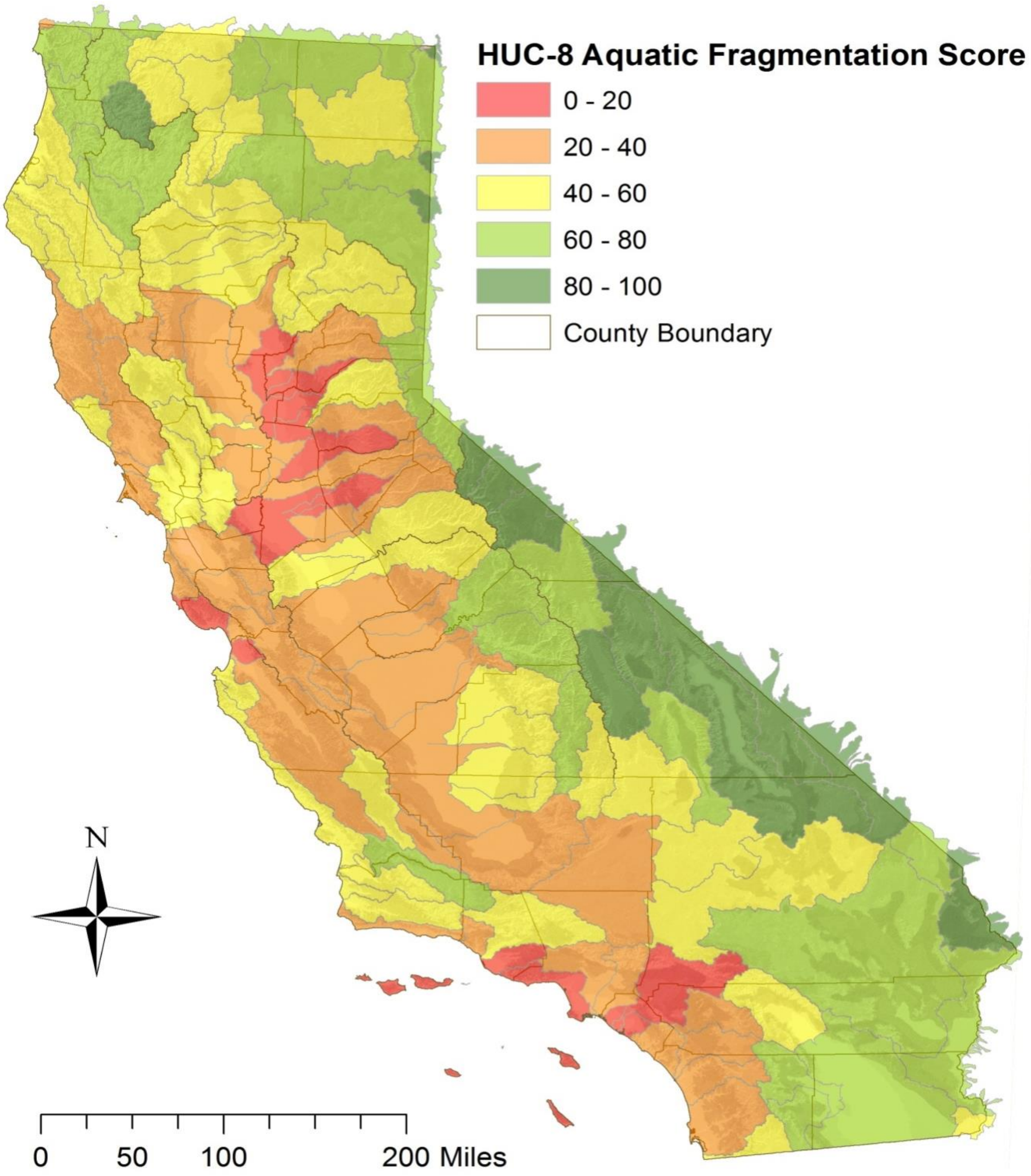


Figure 2. Aquatic fragmentation scores for HUC 8 watersheds. Fragmentation in this case is represented by road-stream crossings.

Temporal and spatial resolution

The assessment is for existing levels of fragmentation, using data developed up to 2011. Although stream extent and position are unlikely to have changed, more recently developed roads in forested and residential areas will not be represented by the analysis. Although the fragmentation effect is at the point of the road-stream intersection, the ecological effects will be felt upstream and downstream to varying degrees depending on the organisms and processes of concern. Therefore, the structural interaction of road and stream is only a general proxy for effects expressed further away.

Technical Information

Data Sources

- Passage Assessment Database (PAD)
- USGS Digital Elevation Data
- CalTrans Roads and Highways
- Forest Service (Region 5) Routes
- National Hydrography Dataset

Data Transformations and Analysis

We used stream and river data from the NHD and road locations from Caltrans and the Forest Service. We first identified points where roads intersected stream systems and created a layer based on these points. Then, using NHD stream data, we calculated the density of intersecting points per unit length of stream and or river. This value was used to create a map illustrating the percent fragmentation within each HUC 12 watershed due to stream and road intersections.

The Passage Assessment Database is useful for estimating the effects of dam locations at the watershed scale. To use these data, some manual editing of spatial data is needed, because some dam locations are not on waterways in the National Hydrography Dataset. Points are first deleted that do not represent artificial boundaries to aquatic life, and points that are not identified as dams per the NHD metadata. Second, aerial photographs (USGS imagery via Google Earth and ESRI) of the area surrounding each PAD dam data point is used to delete or move the location of PAD points. Because of this required data modification, there may be some uncertainty regarding the placement of data points, and thus the resulting watersheds created using PAD points as “pour points” in the watershed model.

2. California Stream Condition Index

Stream and watershed condition based on composition of benthic macroinvertebrate communities relative to expected composition.

Sustainability Goal:

Goal 5. Protect and enhance environmental conditions by improving watershed, floodplain, and aquatic condition and processes.

Sustainability Domain:

Ecosystem Health = The condition of natural system, including terrestrial systems interacting with aquatic systems through runoff pathways.

What is it?

The presence and abundance of aquatic plants and animals can provide an indication of waterway and landscape disturbance, geomorphic conditions, appropriate water availability, and water quality. Comparing the measured presence (observed) of native species or groups to the expected presence of these species or groups is one way of measuring watershed and waterway conditions. The California Stream Condition Index is based on the comparison of the observed assemblage of benthic macroinvertebrate species to those expected from studying reference streams. It provides a scientifically robust way of assessing and describing conditions and tracking conditions over time or in response to regulatory or restoration actions. The State Water Resources Control Board has adopted the CSCI as a defensible and useful indicator of water quality and stream disturbance.

Benthic invertebrates are common, respond to environmental influences, and occur as diverse assemblages. By counting the number of individuals of different taxonomic and functional groups, assemblages can be described and inferences drawn about their aquatic environment. The Index uses comparisons of assemblages at "test" sites with "reference" (less-disturbed) sites, while taking into account natural variation. The Index has two components: 1) ratio of observed to expected taxonomic groups, and 2) proportion of the assemblage that falls into different functional groups that represent species diversity, ecosystem function, and sensitivity to stress. The Index is not normalized to a 0 to 1 or 100 scale, but instead compares Index values at test sites to values at comparable reference sites. The mean Index value of reference sites is 1.01. The 90th percentile value is 0.85. Streams with values >0.85 are considered to be "likely intact". The 99th percentile value is 0.72. Streams with values between 0.72 and 0.85 are considered to be "likely altered" and streams with values <0.72 are considered to be "very likely altered".

Why is it Important?

The best way to assess the ability of a watershed to support living things is to look at those living things. Unlike chemical monitoring, for example, which provides information about water quality at the time of measurement, monitoring of living organisms (biomonitoring) can provide information about past and/or episodic pollution and the cumulative effects of a suite of watershed impacts. BMI represent ideal biomonitors for assessing the overall health of watersheds for a number of reasons:

1. They are widespread
2. They are easy to collect and identify

3. They are relatively sedentary and long-lived, so reflect the longer-term effects of activities within their watershed
4. Some species of BMI are highly sensitive to pollution

BMI-related metrics (e.g., taxa richness and diversity, specific taxa pollution sensitivities/tolerances, etc.) have been used by varied US agencies for many years as “bioindicators” of water quality, providing integrated information on toxic chemical concentrations, dissolved oxygen levels, nutrients, and habitat quality. Beyond their usefulness as bioindicators BMI are themselves an important part of aquatic food chains, especially for fish. Many BMI feed on algae and bacteria, which are on the lower end of the food chain. Some shred and eat leaves and other organic matter that enters the water. Because of their abundance and position as “middlemen” in the aquatic food chain, BMI play a critical role in the natural flow of energy and aquatic nutrients in streams, lakes and wetlands.

What is the target or desired condition?

The CSCI was developed by the State Water Resources Control Board as a regulatory and informational tool to measure and protect water quality and stream processes. The desired condition is for streams to support native species and natural processes, including healthy trophic interactions and the full complement of expected species. The CSCI was developed using reference and test, or disturbed streams. The numeric desired target is the mean of the reference conditions (Figure 1; CSCI value = 1.01). The undesired condition is the absence of any expected native benthic macroinvertebrate species (CSCI value = 0).

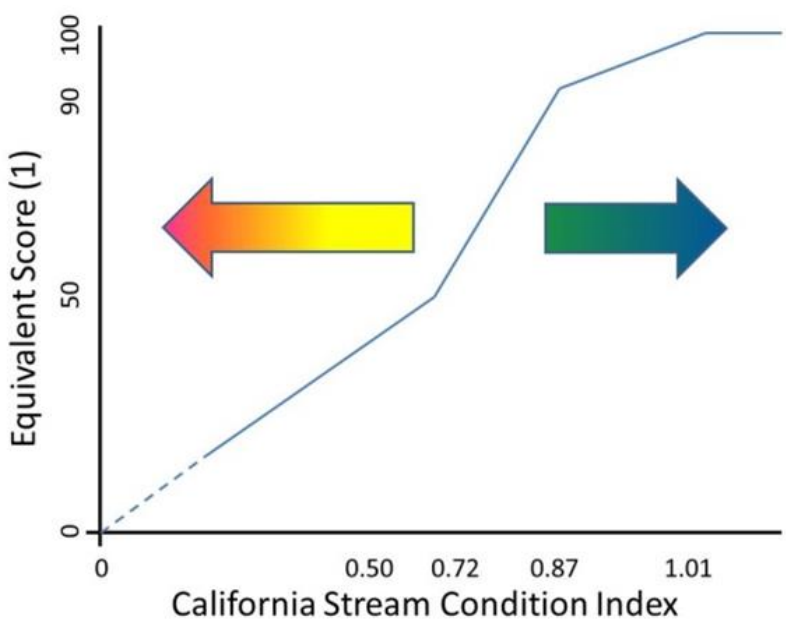


Figure 1. California Stream Condition Index (CSCI) scoring curve. CSCI raw values are on the x-axis and the equivalent score on the y-axis.

What can influence or stress condition?

Many BMI are highly sensitive to changes in their aquatic environment and thus can act as continuous monitors of the condition of the water they live in. Human activities that interfere with or disrupt natural processes in a watershed can have significant impacts on the types and numbers of BMI that live there. Some BMI taxa require very good water quality, whereas others tolerate a wide range of environmental conditions. Although BMI can move about to some extent, drift downstream, and fly as adults, the aquatic forms generally cannot move quickly to avoid adverse conditions. Deteriorating water and/or habitat quality and pollutants can be expected to kill or at least stress less tolerant BMI taxa and encourage other more tolerant taxa to proliferate.

The CSCI is based upon comparison of an observed assemblage of BMI with an expected assemblage, based upon comparison with reference streams. With climate change, it is conceivable that conditions in streams previously thought of as "reference" will change and likely degrade. Therefore a decision will need to be made about whether or not the CSCI will remain an index of **relative** condition, where the benchmark is changing, or if the conditions that have been established at the creation of the index will serve as a benchmark into the future.

What did we find out/How are we doing?

In general, streams in mountainous areas where CSCI evaluations have occurred are in good shape (Figure 2). Urban and agricultural area streams tend to be in moderate to poor condition. This pattern is largely represented when CSCI scores are aggregated to the hydrologic region (Figure 3).

Summarizing the CSCI data from points to larger extents, such as hydrologic regions, may over-estimate CSCI scores (Figure 3) and give the impression that streams in certain regions are in better condition than they are likely to be. For example, in the Tulare Basin, most CSCI evaluation has occurred in the less-disturbed foothill and mountain watersheds, not in the urban agricultural areas.

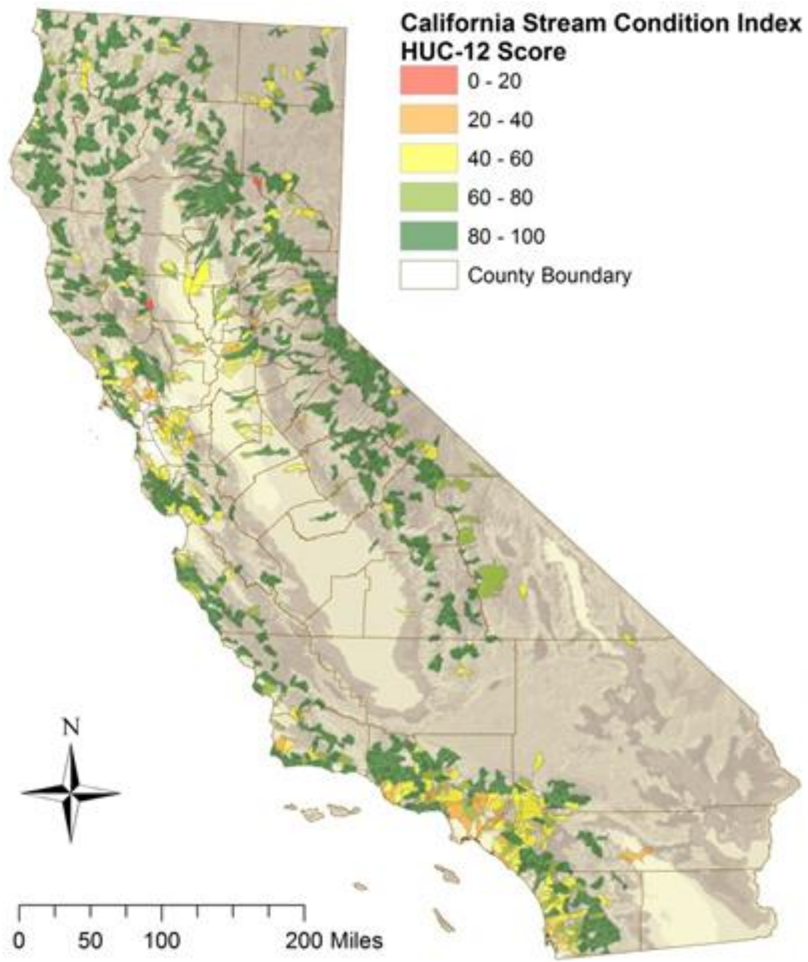


Figure 2. California Stream Condition Index (CSCI) scores for HUC12 watersheds where data collection occurred.

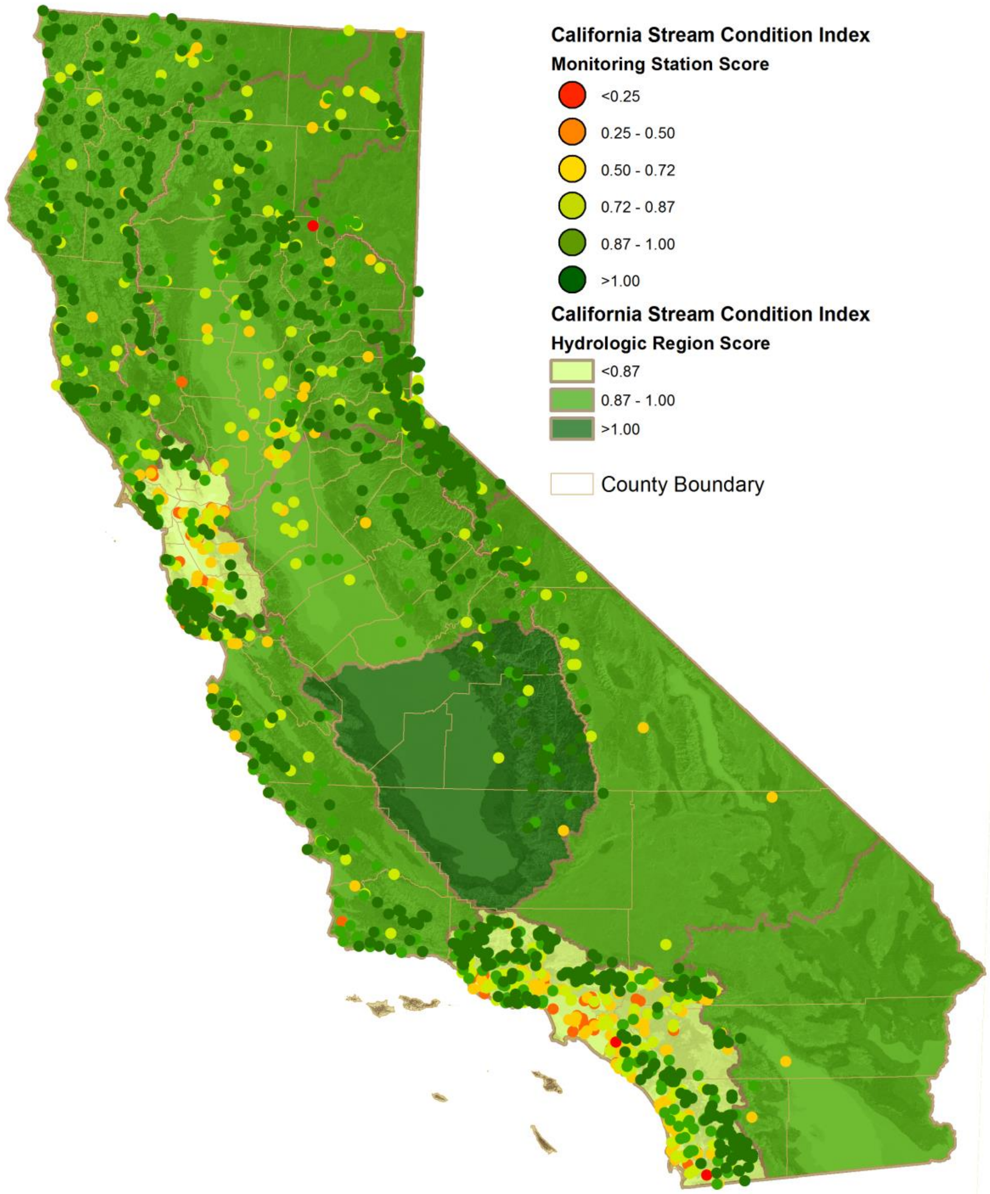


Figure 3. California Stream Condition Index (CSCI) scores for individual monitoring stations and for hydrologic regions

Temporal and spatial resolution

Although the BMI community composition has been assessed at >2,500 sites by California Department of Fish and Wildlife and State Water Resources Control Board staff and others, there are still many streams and other waterbodies in California that have not been assessed. The dataset can be characterized as incomplete in terms of the extent of the state's water. At the scale of individual river basins and regions, there may be many sites that have been evaluated and for others, there may be few or no site evaluations. The degree to which conditions and CSCI values at a site represent upstream conditions depends on the size and natural processes of the upstream watershed. Assessments in the dataset used here have occurred over the last 10 years and no one year provides a statewide assessment of condition. Because this critical indicator has only received limited funding over the years, the technical team has concentrated its efforts in individual regions (e.g., the South Coast hydrologic region) and rotated its efforts around the state.

Technical Information

Data Sources

Data were obtained from the State Water Resource Control Board staff and contractors Peter Ode and Rafael Mazor.

Data Transformations and Analysis

For HUC 12 and HUC 8 watershed units and for hydrologic regions (HR), the average CSCI was calculated for monitoring stations within each unit. Not all HUC 12 and HUC 8 units had been assessed. The equivalent score was calculated for the average CSCI within each spatial unit using the curve below. For CSCI values >1.01 (the mean value for reference conditions), the score was 100. For CSCI values between 0.87 (lower end of the range of reference conditions) and 1.01, a proportional score between 90 and 100 (respectively) was given. For CSCI values between 0.72 (moderately disturbed) and 0.87, a proportional score between 50 and 90 was given. For CSCI values <0.72, a proportional score was given where a CSCI value of 0 would receive a score of 0.

3. Geomorphic Effects of Impervious Surface

Proportion of watershed covered with impervious surfaces, including roads, parking lots, pavement, buildings, and turf grass.

Sustainability Goal:

Goal 5. Protect and enhance environmental conditions by improving watershed, floodplain, and aquatic condition and processes.

Goal 6. Integrate flood risk management with other water and land management and restoration activities.

Sustainability Domain:

Ecosystem Health = The condition of natural system, including terrestrial systems interacting with aquatic systems through runoff pathways.

What is it?

The greater the proportion of watershed with impervious surfaces, the greater the likelihood of geomorphic processes and conditions being degraded due primarily to modifications of stormwater runoff dynamics. Impervious surface is a measure of land cover. It is derived from the National Land Cover Database using satellite imagery primarily from Landsat. Images are analyzed to reveal 16 land cover classes, including: water, developed, barren, forest, shrubland, herbaceous, planted/cultivated, and wetlands. Each land cover class is assigned a value for percent imperviousness based on a 30*30km resolution raster data set (USGS National Landcover Database). It is important to note that the percent impervious surface measurement is an estimate of imperviousness and not a direct measurement.

This indicator covers a process category and serves as a potential measure of impact of development on geomorphic processes, which includes channel, bank, and floodplain functions and processes.

Why is it Important?

Impervious cover is a relatively easily measured metric that is valuable for watershed planners, storm water engineers, water quality regulators, economists, and stream ecologists (Schueler et al. 2009). It also acts as a measure of development and growth. Direct impacts of impervious surface development include changes in natural and agricultural land cover, hydrology, geomorphology, and water quality. Indirectly, impervious surface development impacts stream ecology, species richness, the economy, policy, and social well-being and human health. Bellucci (2007) cites multiple papers documenting the influence of land cover change on stream health, biotic integrity, and runoff; stating that increases in urbanization results in stormwater runoff that contributes to "flashier hydrograph, elevated concentrations of pollutants transported from impervious surfaces to streams, altered channel morphology, and reduced biotic integrity with dominance of more tolerant species."

Basis of calculation and use

For the purposes of our analyses, we used impervious surface spatial data from the years 2001 and 2006. Spatial data for 1992 exists, but represents land cover classes, not impervious surface classifications. Methods exist for assigning impervious surface values for these land cover classes, but are location and scale dependent (e.g. Sacramento, San Diego river) and differ in accuracy (McMahon 2007).

One area of interest in the impervious surface indicator is the degree and pace of change over time. Currently data for percent impervious surface is available for 2001 and 2006, with the following important note for comparison between years from the NLCD website: "NLCD2001 Version 2.0 products must be used in any comparison of NLCD2001 and NLCD2006 data products." Furthermore, with regards to analysis using land cover and estimates in impervious surfaces, McMahon (2007) states the importance of resolution in data for informing land cover classes and developing models for impervious surfaces.

What is the target or desired condition?

There are many estimates for a threshold of percent impervious surface, beyond which, measurable damage to stream systems is endured. Wang et al. (2003) estimate that between 6-11% impervious area, major changes in stream fish could occur. Fitzgerald et al. (2012) estimate increased sensitivity of stream ecosystems at between 5-10% impervious surface. Hilderbrand et al. (2010) suggest that within their study area, once percent impervious area reaches 15%, a loss of nearly 60% of benthic macroinvertebrate taxa could occur. Schiff et al. (2007) calculated that above a critical level of 5% impervious surface, stream health declines. However, Allan (2004) makes the argument that although there is strong influence on stream health and land cover change, direct associations are complex and depend on anthropogenic and natural gradients, scale, nonlinear responses, and the difficulty in parsing out impacts from today and the past.

Thus, modeled predictions that utilize actual monitoring data for regions of interest, the stream indicators of greatest concern, the main land cover type, and represent a range of possible outcomes may be more realistic (Schueler et al. 2009). Furthermore, Schueler et al. (2009) mention several caveats regarding the use of impervious surface as an indicator for stream hydrology and health. These caveats include: consideration of watershed scale, problems with forming relationships between impervious surface and watersheds with major point source pollutant discharge or dams, importance in grouping watersheds within the same physiographic regions, and caution when applying models based on impervious surface when management practices are poor, especially in areas of low impervious cover (Schueler et al. 2009).

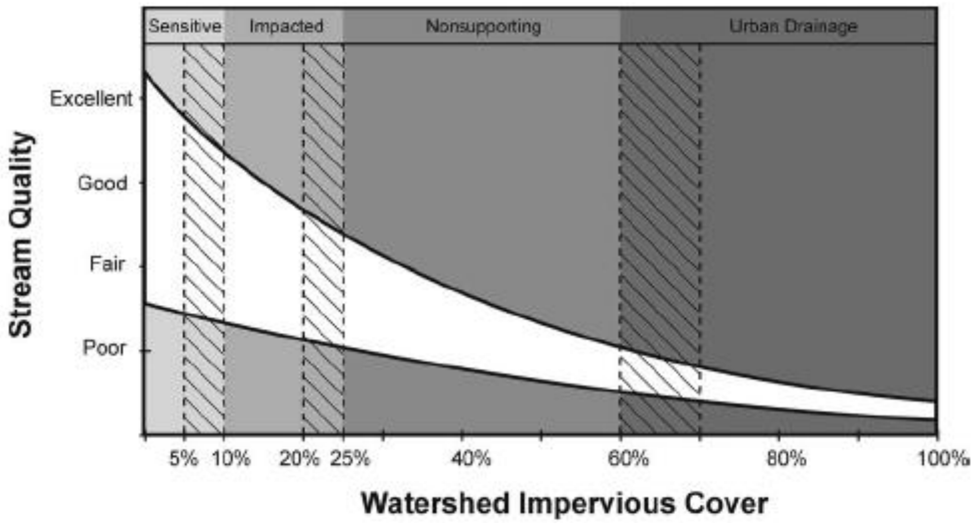


Figure 1. Conceptual model of impervious surface. This illustrates a range in stream quality as a result of impervious cover and the wide variability in stream indicator scores for impervious surface cover below 10% (Schueler et al. 2009).

What can influence or stress condition?

Development or conversion of land from "natural" to agricultural land is the only thing that could alter this condition. Furthermore, as stated previously, changes in land cover can indirectly affect geomorphology, water quality, and ecosystem health in terms of native species richness.

Climate change may influence the resulting geomorphic condition scores by altering the timing and amount of precipitation as well as drought. Climate predictions result from a combination of scenarios and climate models that integrate estimates of greenhouse gas emissions and how the climate system will respond to these emissions. Therefore, variation within the predictions may result in different policy implications and actions. Furthermore, we are likely to see variation in the location, amount, and timing of precipitation rather than homogenous responses across the globe.

What did we find out/How are we doing?

Out of 4,637 watersheds, the mean percent impervious area for the state of California is 2.6%, with mean percent impervious area of watersheds ranging from 0-68.8% impervious area. This value comes from an already calculated mean of impervious surface raster values and is the mean of this for all the watersheds under hydrologic unit codes classified as "HUC12". The mean score for the geomorphic condition is 95, with mean scores for HUC12 watersheds ranging from 30 to 100 (Table 1).

Table 1. Summary statistics for mean impervious area, geomorphic condition (GC) scores for the entire state of California (averaged among all watersheds with HUC 12 classification).

	Mean Percent Impervious	GC score
Mean	2.6	95
Standard Error	0.12	0.00
Median	0.24	100
Mode	0.00	100
Standard Deviation	8.2	14
Range	68.8	70
Minimum	0.00	30
Maximum	68.8	100

A previous study by Xian et al. (2011) calculated an increase between 2001 and 2006 in impervious area of 852.13 km2 for California. These changes make California the second fastest growing state in the country, behind Texas.

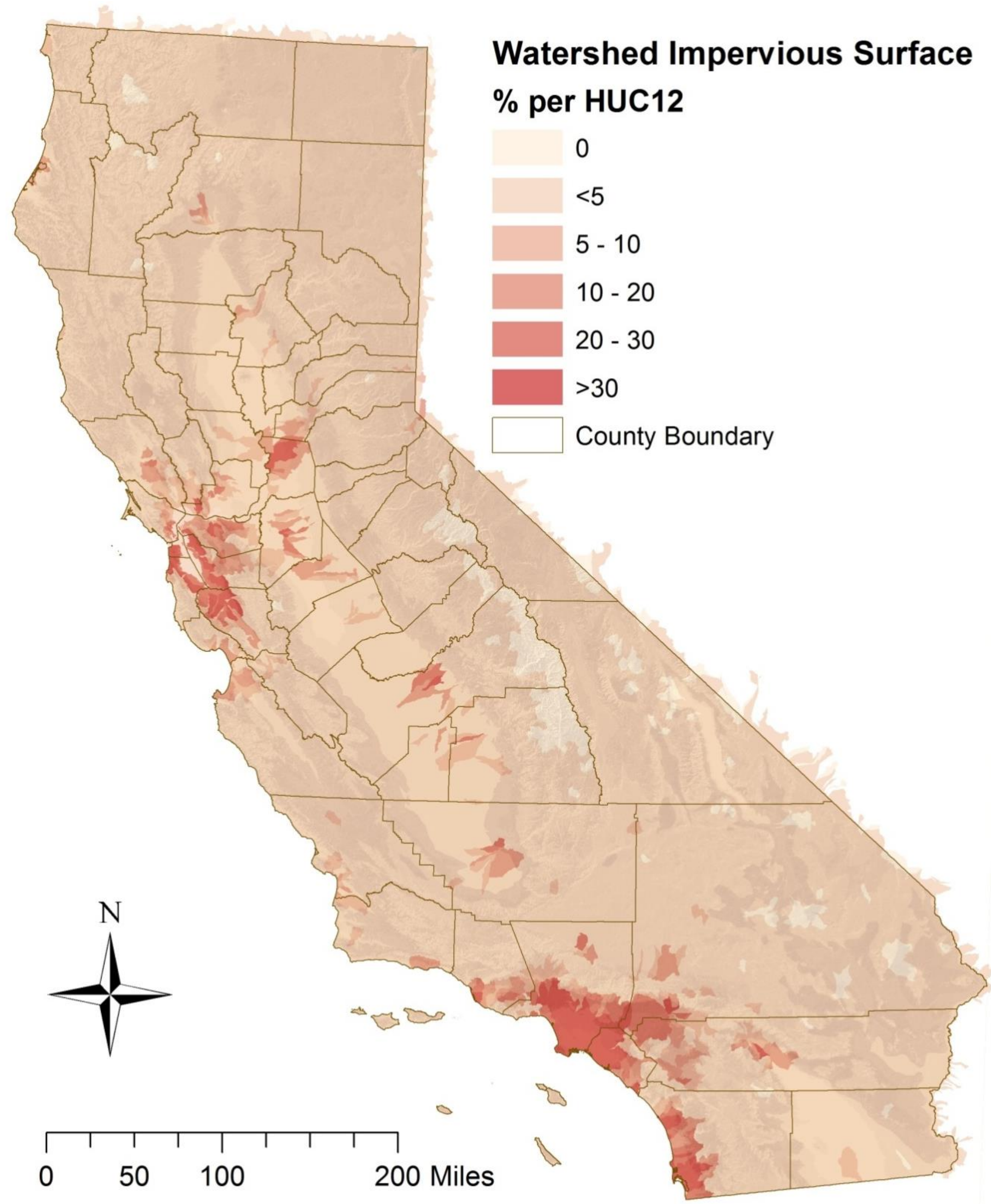


Figure 2. This map illustrates the mean percent impervious cover for each watershed with the hydrologic unit code classification of "HUC12".

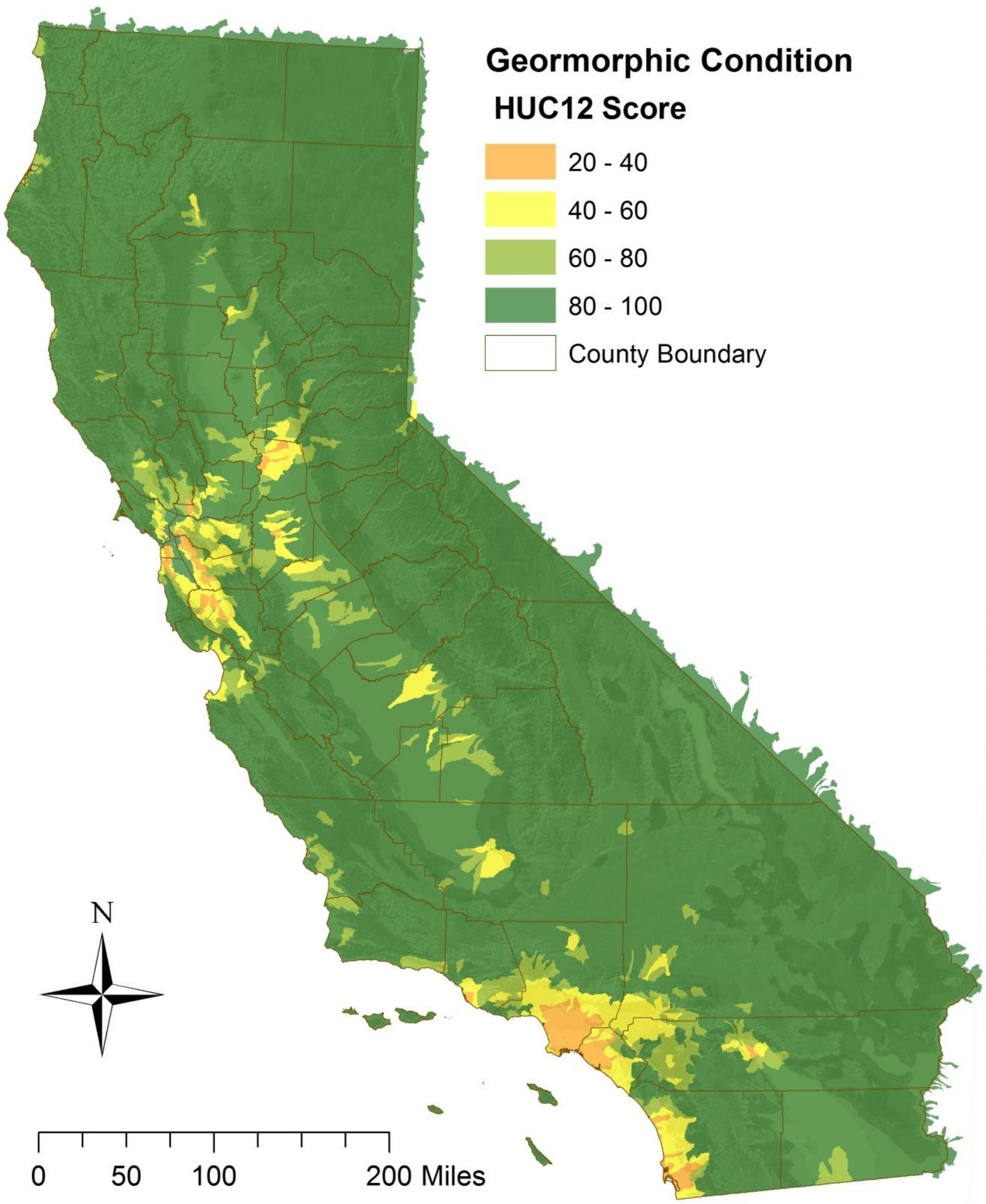


Figure 3. This map illustrates the geomorphic condition scores for each watershed with the hydrologic unit code classification of "HUC12".

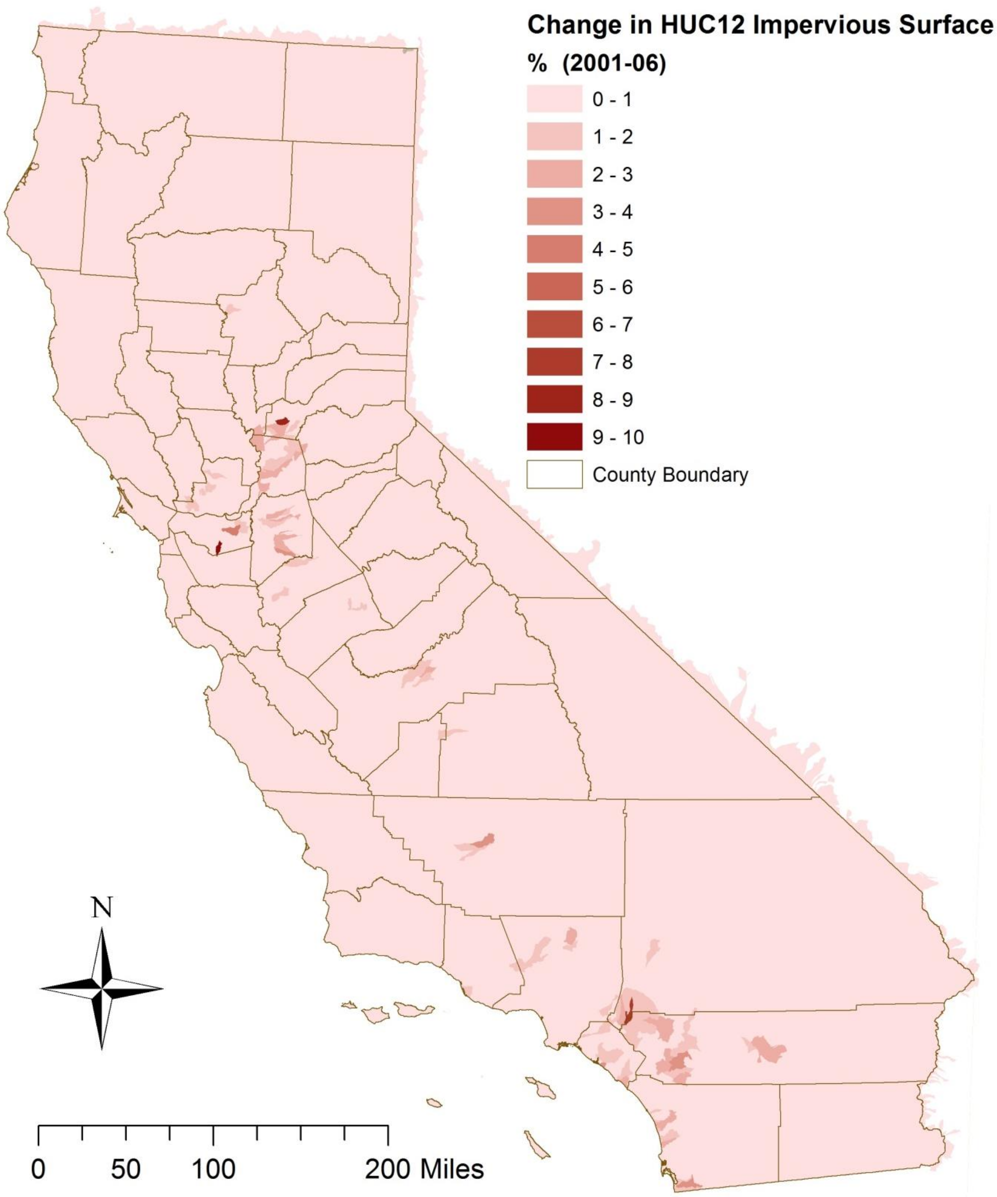


Figure 4. This map illustrates the change in mean percent impervious cover for each watershed with the hydrologic unit code classification of "HUC12" between the years 2001 and 2006.

Temporal and spatial resolution

Although percent impervious surface can be aggregated or displayed at the state level, it is more informative at smaller spatial scales that are appropriate to the analysis at hand. This is because the response of water quality, hydrology, and biotic condition to impervious surface will depend on the location and the scale of measurement. For example, when looking at fish richness, grouping physiographic regions or ecoregions based on species habitat requirements is more informative in developing predictive models than when examining the entire state of California with all its diverse aquatic habitats. Other considerations might include particular habitats, topographies, climates, and even degrees of development, both urban and agricultural.

Knowledge of local scales is also vital when percent impervious surface is simply used as an indicator to track speed and direction of development. For example, the rate of change in impervious surface between 2001 and 2006 was greater in the Sacramento are than in Los Angeles (Figure 5). But, the highly-developed Los Angeles region may, require more conservation action to protect or reverse negative impacts of impervious surface than the Sacramento region, while the Sacramento region still has some land not yet impacted by imperviousness, but could be managed to prevent many negative side effects. Therefore, it is important to remember that the state-wide analysis is best used as a starting point from which local analysis and policy decisions can be made.

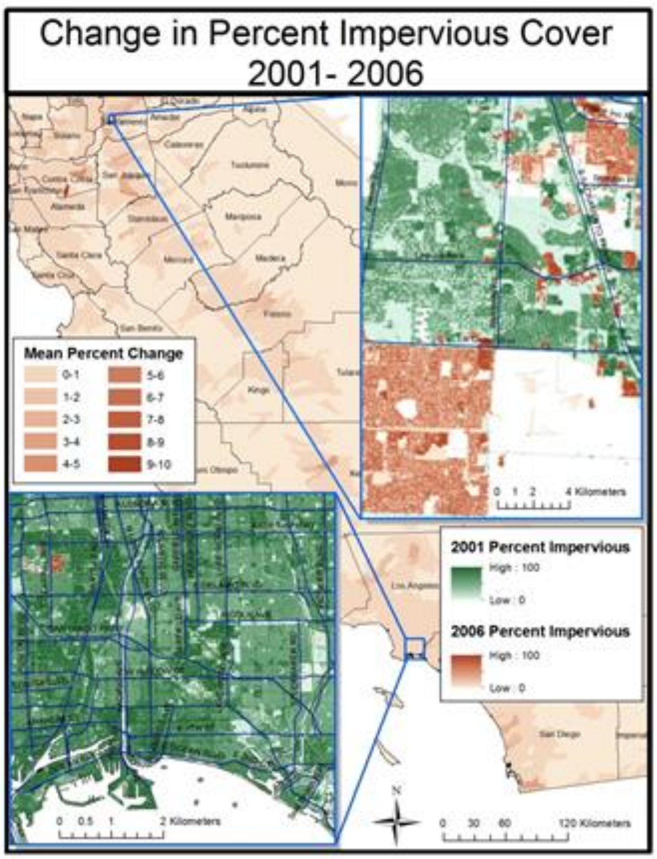


Figure 5. This map illustrates the both the change in mean percent impervious cover for each watershed with the hydrologic unit code classification of "HUC12" and the actual raster datasets for map extents covering the Sacramento and Los Angeles regions.

How sure are we about our findings (Things to keep in mind?)

The NLCD analysis is not perfect. Interpretations in land cover based on satellite imagery and subsequent applications of models to determine the percent impervious cover for the years 2001 and 2006 may not be wholly precise, but serve as a good estimate of impervious surface throughout the United States.

Our analysis relies on the zonal statistics function in ArcMap, which averages the raster values for percent impervious surface throughout the entire watershed. This removes the ability to detect finer-spatial changes in percent impervious surfaces (see Figure 5). Thus, calculations of geomorphic conditions from these statistics are not perfect, but represent a starting point from which more detailed analysis on finer spatial scales can begin. Ninety-five percent confidence intervals of the mean percent imperviousness were calculated for each sub-watershed, so some degree of understanding about our confidence in the mean values can be assessed. For example, figure 6 illustrates the frequency of 95% confidence intervals for all the watersheds. It is clear from this figure that confidence intervals are very small (<1%) for most watersheds.

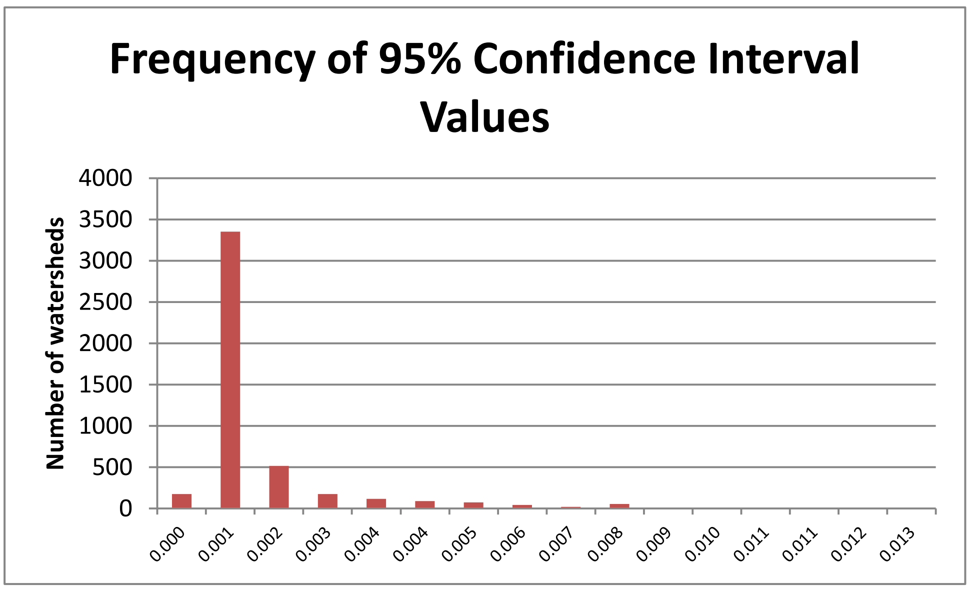


Figure 6. Frequency of 95% confidence intervals across HUC12 watersheds.

Technical Information

Data Sources

Spatial data for the impervious surface analysis come from:

1) United States Geological Survey
   a) National Land Cover Database
      i) Spatial data for years 2001 and 2006

ii) Change in percent imperviousness
iii) Percent Imperviousness

Data Transformations and Analysis

Data were downloaded from the NLCD database in zip files that included raster files for import into ArcGIS. We used Arc GIS spatial software to display percent impervious surface throughout California. To illustrate effects on individual watersheds we used Hydrologic Unit Codes representing the smallest sub-watershed level (HUC 12). Zonal statistics within each sub-watershed resulted in means and standard deviation from which 95% confidence intervals were calculated. To illustrate change in percent impervious surface, zonal statistics were performed on spatial data for the change of impervious surface between the years 2001 and 2006. Because of challenges in comparing NLCD datasets from these two years, we used spatial data calculated by Fry et al. (2011) and Xian et al. (2011) for our analysis.

Geomorphic Condition

The geomorphic condition (GC) indicator is a measurement of the condition of geomorphology of a watershed based on the channel and floodplain geometry and planform, bed substrate, bank erosion, and bank and buffer vegetation. A composite calculation for GC was developed using four "adjustment processes" assigned 20 points each, are summed, and then normalized to develop a score ranging from 0 to 100. These "adjustment processes" are: Channel degradation, Channel aggradation, Channel widening, and Change in planform. A line was fit to the normalized GC scores associated with the total percent impervious area using a stepwise regression analysis and the addition of "other natural watershed characteristics" for high-gradient and low-gradient study reaches (Fitzgerald et al. 2012). The line for the high-gradient reach represents the model used in our analysis (see Figure 7 and Equation 1).

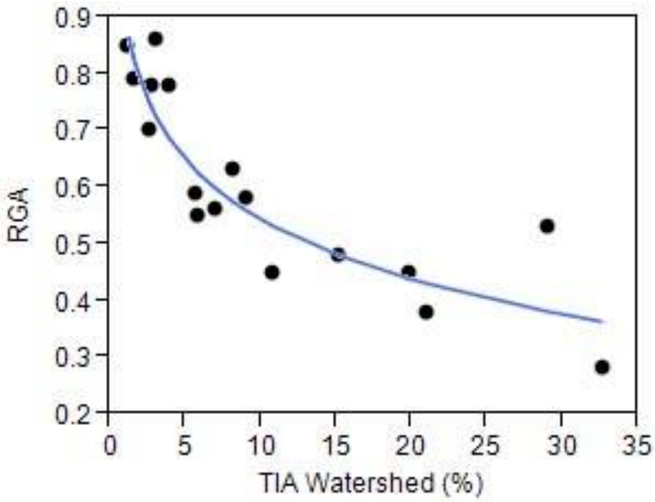


Figure 7. Plot of the relationship between GC and percent upslope total impervious area (TIA) for high gradient study reaches. (Adapted from Fitzgerald et al (2012).)

$$Euaqtion\ 1: GC = 0.197 - 0.15logTIA *$$

*The equation should be interpreted as natural log (ln) of mean Total Impervious Area (TIA) per HUC12 watershed.

Because the scale is already normalized between 0-1, we used the raw GC calculation in our depiction of RGA for each sub-watershed.

4. Groundwater Quality

Groundwater quality and threats to quality from nitrate and other sources of contamination.

Sustainability Goal:

Goal 4. Improve quality of drinking water, irrigation water, and in-stream flows to protect human and environmental health.

Sustainability Domain:

Water Quality = The chemical and physical quality of water to meet ecosystem and drinking water standards and requirements.

What is it?

Groundwater describes water in soil and sub-soil substrates (e.g., aquifers) that is replenished across various time-frames by surface water that percolates to these underground reservoirs. Groundwater interacts with surface water through natural (hydrologic connectivity and flow;

Barlow and Leake, 2012) and artificial (over-pumping and discharge) pathways. For this water to be useable to meet human needs (e.g., drinking, irrigation) it must meet the same kinds of water quality requirements as surface water. Two indicators were chosen to represent groundwater quality: 1) nitrate concentration as a direct measure of quality; 2) whether or not an area/community has safe drinking water (SWRCB, 2013); and 3) whether or not an area contains "threats" to groundwater according to CalEnviroScreen (CalEPA, 2013).

Why is it Important?

Groundwater is the primary source of drinking water for many communities in California. Groundwater quantity and quality is also under threat from over-use and contamination from surface water and soil contamination. Degradation of groundwater quality jeopardizes use of this resource for drinking water. California's Drought Contingency Plan (DWR, 2010) depends on groundwater as part of its "Conjunctive Management and Groundwater Storage" and "Recharge Area Protection" strategies. In order for these measures to function as part of the overall plan, then groundwater quality must be high enough to support human use.

Nitrates are the primary (most extensive) contaminant in groundwater originating from human activities. Nitrates from fertilizer application in agricultural and urban areas, as well as other sources like livestock rearing, can leach into groundwater and will penetrate and spread according to the underlying geology. Other contaminants can also affect groundwater, including organic chemicals originating from past and current industrial and commercial activity. This contamination may spread underground in "plumes", which are areas of increasing concentration as contaminated groundwater naturally moves underground, or the chemicals themselves diffuse through the ground and/or water. Various agencies track these contaminants in groundwater and in drinking water wells originating from groundwater as a way of understanding risk to communities from drinking water contamination.

What is the target or desired condition?

The desired target condition is for groundwater to be free of artificial contaminants. The undesired condition is for groundwater to violate drinking water standards set by environmental regulatory or health agencies, or to pose a risk of violation.

1) Nitrates: Desired condition is for groundwater to have nitrate concentrations at or below naturally-occurring background concentrations. According to Harter et al. (2012), background nitrates concentrations in the Tulare Lake Basin are 9 mg/L nitrate. The state and federal drinking water standard (maximum concentration) for nitrate is 45 mg/L nitrate (equivalent to 10 mg/L NO3 nitrogen). This is the undesired condition. http://water.epa.gov/drink/contaminants/basicinformation/nitrate.cfm
2) The State Water Resources control Board recently evaluated drinking water sources for California communities for safety and maximum contaminant level (MCL) violations (SWRCB, 2013). The desired condition was 100% of the population having access to

safe drinking water, score = 100. The undesired condition is attained if >10% of the area population was served by systems with MCL violations and reliant on GW, score = 0. Intermediate scores are calculated using an inverse relationship with the proportion of the population (<10%). For example, if 4% of the population has drinking water with MCL violations, then the score = 60.

3) The CalEnviroScreen 1.0 project is a systematic look at the environmental threats to health (e.g., from poor air quality) to people in California (OEHHA, 2012). The CalEnviroScreen suite of indicators includes threats to groundwater as one type of threat to health. The groundwater threat score is based upon current or past leaks from underground storage tanks for chemicals. The project analysts used tank locations in the SWRCB's GeoTracker database (http://waterboards.ca.gov) and rated each site based on type and cleanup status. Scoring here was the corollary to the groundwater threat score and was equal to 100 - threat percentage score. So, if the threat percentage score was 25, then the sustainability score would be 100-25=75.

What can influence or stress condition?

Groundwater naturally varies in quality based on underlying geology and interaction with percolating surface water. Groundwater contamination by any chemical will decrease or increase due to penetration of less or more-contaminated water, respectively. Groundwater concentrations of nitrate increase due to leaching of nitrate from various agricultural and urban activities, such as: surface application of fertilizer, confined animal feeding operations, and septic tanks. In mining and urban areas, commercial and industrial activities can result in inorganic and organic chemicals leaching into local and regional groundwater. In areas where these resources are particular valuable or threatened, wells may be used to extract and treat contaminated water, usually at great expense. In other areas, introduction of captured storm-water or surface water could be used to dilute contaminants in groundwater.

What did we find out/How are we doing?

Roughly a third of the state has some threat or actual degradation of groundwater quality (Figures 1-3). This is mostly concentrated in agricultural and urban areas. The sources and causes of impairment vary based on the overlying land-use, legacy of previous land and water uses, and continued management of the groundwater basins. Comparison of the three maps (Figures 1 -3) show that a community may have reduced access to safe drinking water (Figure 2) but this may not be obvious from the nitrate concentrations (Figure 1) or CalEnviroScreen groundwater threats (Figure 3) assessments. For example, according to SWRCB (2013) communities in Plumas and Lassen counties have reduced access to safe drinking water (score 0 – 20 range), for which there is only slight indication from the nitrate concentration (Figure 1) and threats to groundwater (Figure 3) assessments and maps. This is in contrast to San Joaquin

County, where there is strong correlation between the poor ranking for communities with safe drinking water (Figure 2) and the scores for nitrate concentrations (Figure 1) and threats to groundwater (Figure 3). The lack of complete correlation among these indicators of groundwater quality indicates that groundwater faces multiple and complex threats, depending on where one is in the state.

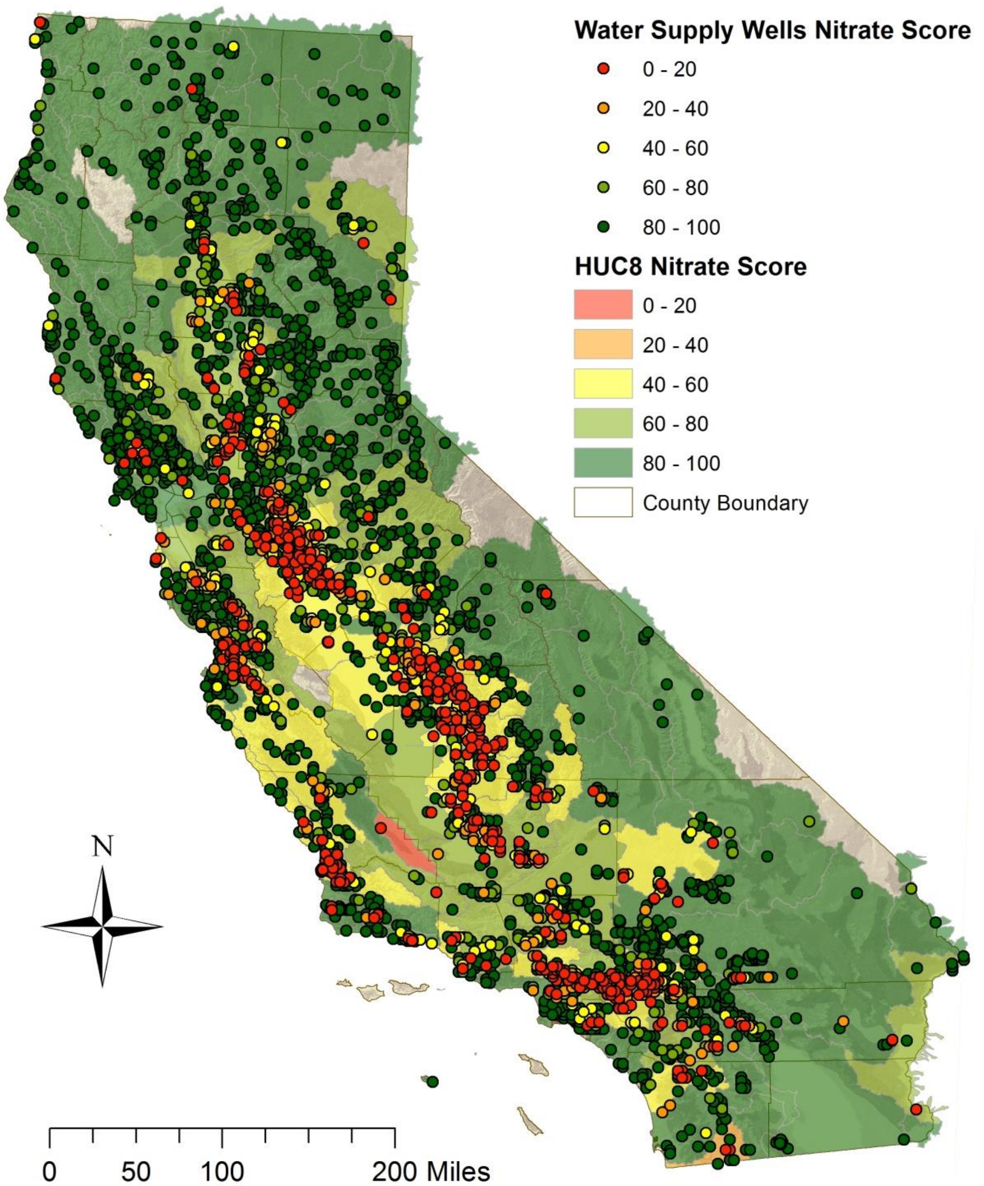


Figure 1. Scores for nitrate concentrations sampled at water supply wells at some point in 2012 and corresponding scores for HUC-8 watersheds. HUC-8 scores were calculated as the average of the well scores occurring within the watershed area. HUC-8 watersheds without scores had not well within them. Data Source = Groundwater Ambient Monitoring & Assessment project (SWRCB).

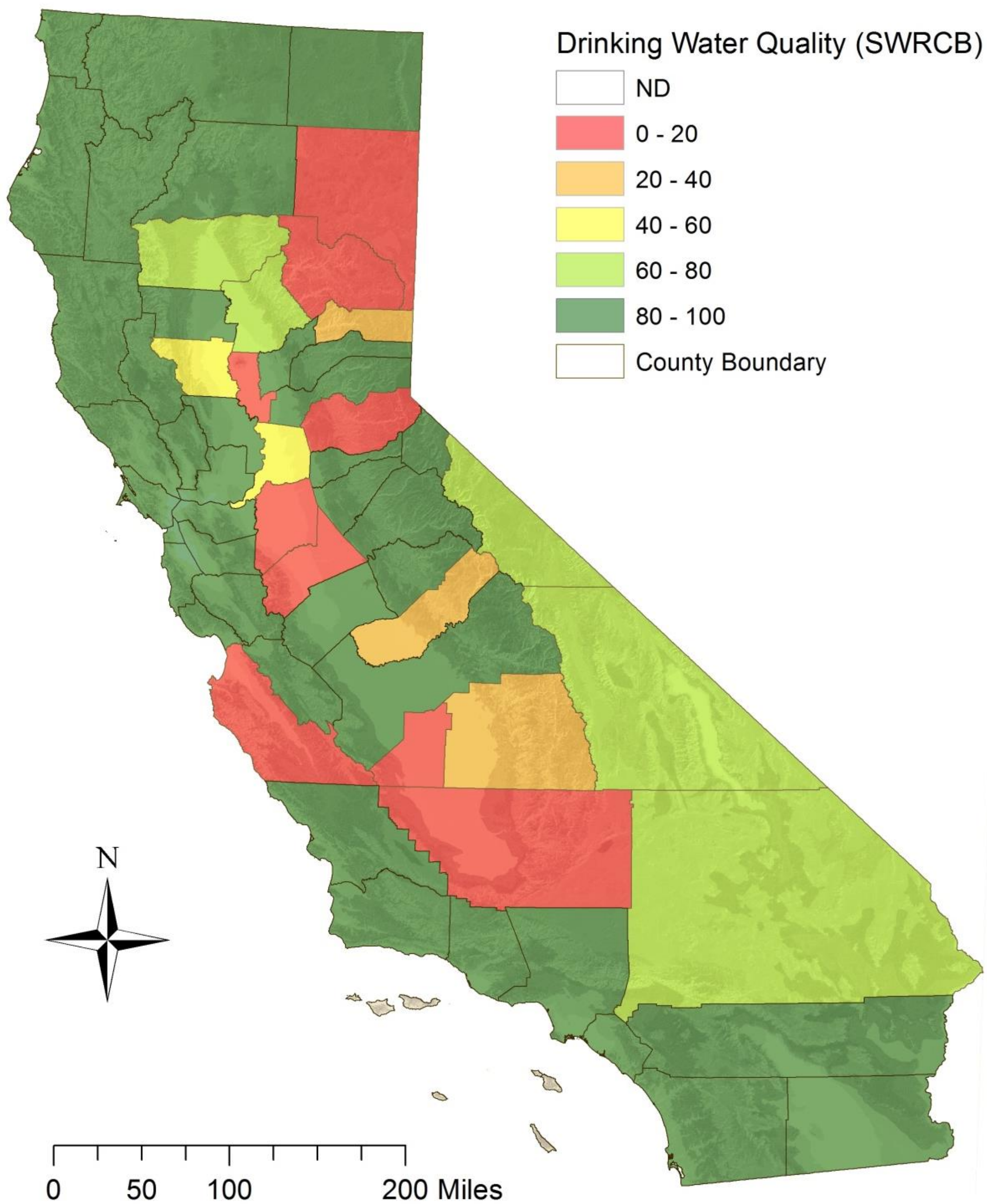


Figure 2. Counties with communities that have drinking water sources with known contamination, based upon violations of maximum contaminant levels (MCL). Data Source = SWRCB, 2013.

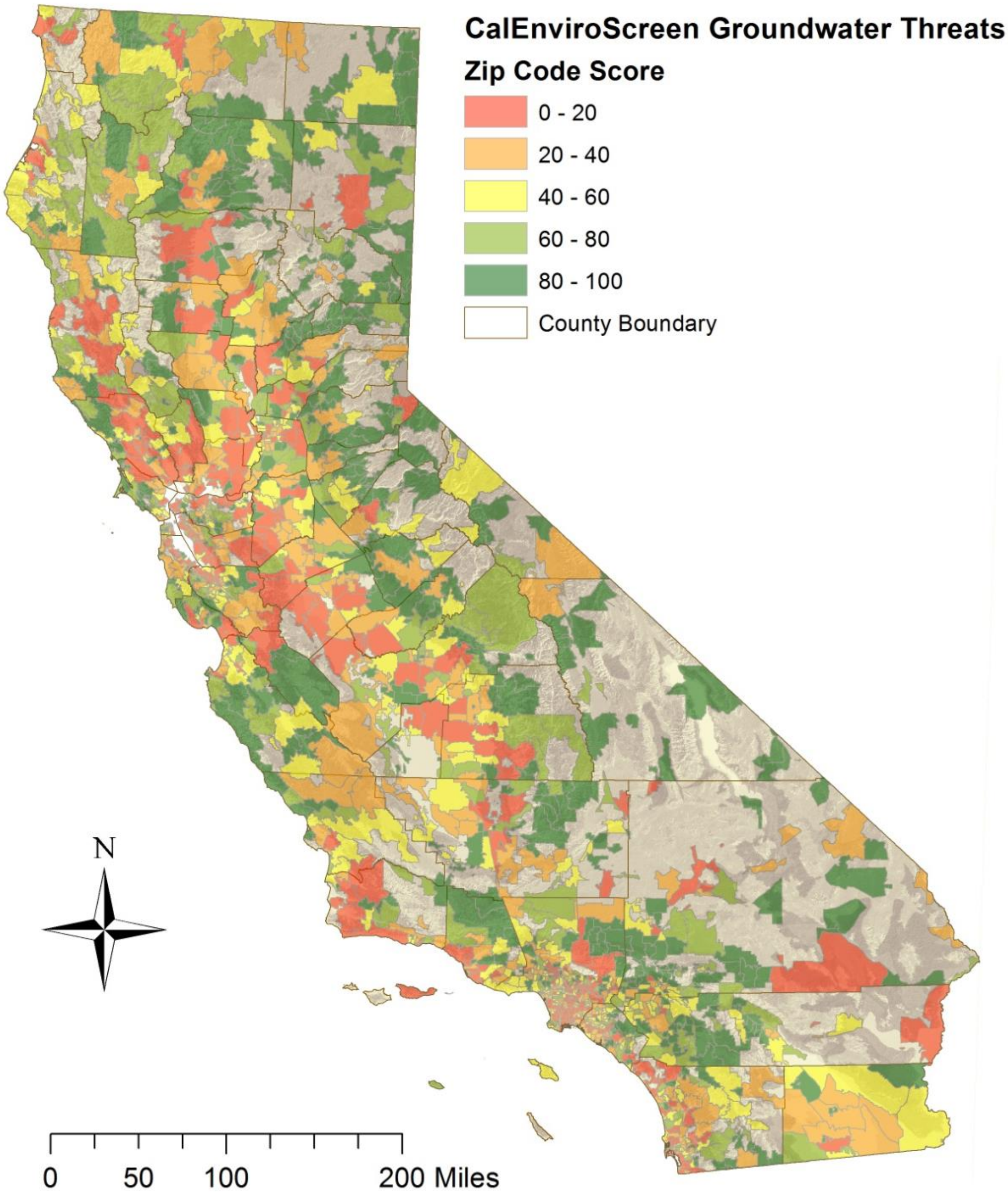


Figure 3. Scores for zip codes with threats to groundwater from leaking underground storage tanks. Data source = CalEnviroScreen 1.0.

Temporal and spatial resolution

Water supply and groundwater monitoring wells occur at a high density in California (Figure 1). The actual locations of the wells are often kept private, meaning that spatial accuracy of the well locations in public databases is unknown. Monthly sampling of well water is common, which is likely to be frequent enough to track changes in groundwater. For wells used as drinking water, more frequent sampling may be carried out. The assessment of risk to groundwater in the CalEnviroScreen study is at the spatial extent of zip codes and in the SWRCB study, at the extent of municipalities. Both zip code service areas and municipalities vary in size across the state, based primarily on population, therefore the grain of analysis is not uniform across the state. The grain of these two studies is not necessarily matched to the extent of groundwater supplies, but may correspond well to population size and groundwater use.

How sure are we about our findings (Things to keep in mind?)

Nitrate concentrations vary considerably across time at individual wells and across time and space at wells that service single municipalities. Because agencies providing drinking water often test water supplies for concentrations nitrate, and other contaminants, they are able to blend cleaner water (low contaminant concentrations) with less-clean water in order to meet drinking water standards. This means that even if a groundwater well has a nitrate concentration that exceeds the standard (45 mg/L nitrate, Figure 1), it may still be used as part of a community's drinking water supply if it is first blended with other water. At the same time, as the proportion of a water supply including high concentrations of nitrate increases, it is less available for use as part of a community's drinking water supply. This means that by themselves, nitrate concentrations for individual wells (Figure 1) indicate groundwater condition, but are only indicative of potential problems with drinking water supply. Cumulative threats to groundwater quality from leaking industrial/commercial sources (CalEnviroScreen), or many sources (SWRCB, 2013), indicate current and future risks to drinking water quality and availability. Continued risks to health and actual exposure of members of the public to contaminants in groundwater through drinking water supplies depends on how the groundwater basins are managed, how contaminating land uses are managed, and how water agencies manage multiple sources of water supplying communities.

Technical Information

Data Sources

1) Nitrate concentrations for individual wells were obtained from the online SWRCB site: http://www.swrcb.ca.gov/gama/
2) Information about communities that rely on a contaminated groundwater source for drinking water was obtained from the report of the same name, available at: http://www.waterboards.ca.gov/water_issues/programs/gama/ab2222/docs/ab2222.pdf.
3) Data for CalEnviroScreen (OEHHA) was obtained from:
    a. CalEnviroScreen data: http://www.oehha.ca.gov/ej/index.html
    b. GeoTracker location of facilities: http://geotracker.waterboards.ca.gov/data_download.asp

Data Transformations and Analysis

Nitrate

Scoring of nitrate concentrations were based on the following curve (Figure 4). Nitrate concentrations <9 mg/L (background; Harter et al., 2012) received a score of 100. Concentrations between 9 mg/L and 45 mg/L (EPA and CalEPA threshold for drinking water) received scores that declined in proportion to increases in concentration. Concentrations >45 mg/L received a score of 0, regardless of magnitude.

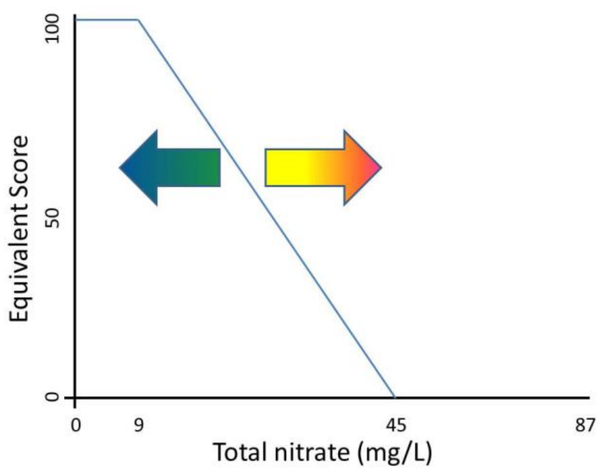


Figure 4. Scoring relationship for nitrate in groundwater used as drinking water supply.

SWRCB Communities with Unsafe Drinking Water

The SWRCB (2013) reported the size of the population with contaminated drinking water. If 100% of the population have access to safe drinking water, then the sustainability score = 100. If >10% of the area population was served by systems with MCL violations and reliant on GW, then the score = 0. Intermediate scores are calculated using an inverse relationship with the proportion of the population (<10%). For example, if 4% of the population has drinking water with MCL violations, then the score = 60.

CalEnviroScreen Groundwater Risk

CalEnviroScreen provides a score for "groundwater threats", based upon the number and extent of threats to groundwater from leaky commercial and industrial systems per zip code area. The sustainability indicator score was calculated as the reciprocal of the "groundwater threats pctl" value from CalEnviroScreen, meaning that a high CalEnviroScreen value (meaning high threat) results in a low equivalent sustainability score. Score = 100 - "groundwater threats pctl". The HUC 8 score was calculated as the mean score for all zip codes within each HUC 8.

5. Native Fish Conservation Status and Community Diversity

Fish community composition relative to historical or reference conditions and conservation status of certain fish species.

Sustainability Goal:

Goal 5: Protect and enhance environmental conditions by improving watershed, floodplain, and aquatic condition and processes.

Sustainability Domain:

Ecosystem Health = The condition of natural system, including terrestrial systems interacting with aquatic systems through runoff pathways.

What is it?

An intact and healthy watershed and waterway network will tend to maintain most or all of the expected native aquatic fauna and flora over any one study period. As disturbance increases, fewer native species will be observed and this ratio will decline. Two types of aquatic animals that have been assessed in California are native (and non-native) fish and benthic macroinvertebrates (primarily early life stages of certain insects). Comparing the observed presence of native fish or other animals to what is expected gives an indication of environmental conditions and disturbance.

Fish indicators have been widely used and recognized as important tools to evaluate watershed and stream ecosystem health. A combination of native fish conservation status and the fish community composition will provide a complete evaluation of the fish condition in California watersheds. Four metrics are proposed for this indicator at the state level:

NATIVE FISH STATUS

- **Conservation status of freshwater fish:** This is an evaluation of the threat status of the 129 freshwater fish native to California that follows a group-specific quantitative protocol detailed in Moyle et al 2011 (see scoring rubric in Sub-appendix 1). Under this protocol there are seven metrics to assess fish threat: area occupied, estimated adult abundance, intervention dependence, tolerance, genetic risk, climate change and anthropogenic causes (including15 related categories). Each species is evaluated separately and then a summary report for the State is produced in terms of total species by threat category. The first specific assessment developed by Moyle et al (2011) was used as the reference evaluation to compare for long-term changes in fish conservation status. Evaluations are suggested to be carried out on a 5-year period.
- **Status of key fish species:** This metric is based on a species-specific assessment of conservation status. Some native species in California are of particular concern due to

the rapid decline of their populations in the last decades. Examples include the Central Valley Chinook Spring-Run Salmon, Coho Salmon, Delta Smelt, Sacramento Perch. To consider few species (2-3) as state key indicators would not be the best approach due to the diverse and distinct biological regions across the state. Therefore, this metric will include 1-2 key fish species per each one of the 6 main zoogeographic regions in California[1]. This metric will use the same threat status quantitative protocol by Moyle et al (2011) and will also include a species-specific distribution range analysis. Species-specific assessments are suggested to be carried out on a 5-year period basis.

FISH COMMUNITY COMPOSITION

- **Percentage of native richness expected:** This indicator compares the native species richness to the expected number of fish species by main zoogeographic/watershed region1. The expected native richness by main watershed region is obtained from Moyle (2002), which provides the historic (pre-1850) native fish diversity. Native richness would be evaluated periodically in a 5-year period.
- **Proportion non-native species:** This metric is the percentage of non-native fish diversity over total fish diversity (species richness) by main zoogeographic/watershed region1. Established non-native species will include species from outside California and also intra-state introductions. A baseline community composition data by main watershed region for long-term comparison and evaluation is provided by Marchetti et al (2004), see Sub-appendix 2.

The fish community evaluation will provide a score on the native/non-native identity that will show how well the main watershed regions in California are supporting fish diversity.

Figure 1 shows a summary of the global indicator for fish status in California. This indicator report suggests using the four metrics detailed above in order to have a complete analysis of fish condition, including threat status and community composition at the state level. However, each one of the four proposed metrics could be evaluated separately depending on the available information and the existence of continuous fish community monitoring in California watersheds.

[1] See Section of temporal and spatial resolution

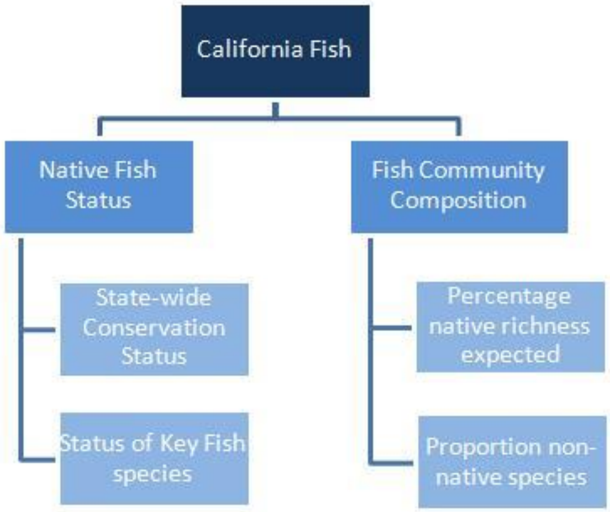


Figure 1. Conceptual model of fish community and conservation indicator.

Why is it Important?

California has 129 native inland fishes, of which 63% are endemic to the state (Moyle et al 2011). Diverse conditions in California have produced fish species that have evolved and adapted independently in isolated watersheds. Fish communities, therefore, are important elements of the state freshwater ecosystems and their status and composition represent good indicators to evaluate disturbances over time.

The fish conservation status indicators provide useful information on threats to native fish and the causes of decline. This information can be used to improve and adapt management decisions, especially to assign resources where is more needed. Also, it can be used to evaluate conservation management efforts directed to restore threatened species and the watersheds or streams where they live. Specific-species assessments complement the state-level status evaluation. Certain species are of great ecological, economic and cultural importance because they are strong indicators of habitat quality in specific watershed systems. Impacts of human activities and climate change have imposed challenges to the survival of these key species, which makes stronger the need of a long-term monitoring of their status to ensure their conservation.

Measures of fish community composition that compare native diversity to non-native diversity provide an indicator of biotic integrity. The difference between the current native fish assemblage and the historical native fish assemblage indicates how well the watershed or streams are doing in supporting the natural functional diversity. Either low native species richness relative to expected or high percentage of exotic species show that the system is departing from its natural balance and that the watershed ecological health is declining (Meador et al 2003). In meadow systems of the Sierra Nevada montane watersheds, for example, dominant salmonids are non-native, which indicates a considerable alteration of the historic fish fauna in these meadow systems (Purdy et al 2011). Moreover, the composition of fish fauna in watersheds can also be correlated to the composition and status of other fauna groups (e.g., native amphibians decline after the stocking of non-native trout; Knapp, 2005).

What is the target or desired condition?

NATIVE FISH CONSERVATION STATUS

For the conservation status of native fish, the ideal condition is that no species become extinct or endangered and the ones in these categories recover over time and become assessed under a low extinction risk category. Based on the quantitative protocol used for the fish conservation status assessment (Moyle et al 2011), the desired target is that all native fish species reach a conservation score of 5, indicating that there is no negative impact on status.

FISH COMMUNITY COMPOSITION

The desired condition is that native fish communities will be fully intact, that they will conserve or resemble the historical natural assemblage (100% similarity), and there are no invasive species. Each watershed is given a score dependent on the ratio of current richness over historic richness. Scores equaling 100 represent no loss in richness over time or even gains in richness. A score of 50 represents a loss of 50% richness between the historic and current species richness in each HUC12. A score of 0 represents no current range contributed to the richness in that particular HUC12. A full list of the species in this analysis is available in Table 1.

What can influence or stress condition?

Stressors of native fish communities in California are several, including habitat conversion and degradation, impacts of anthropogenic activities and introduced species. A recent analysis on the conservation status of native fish in California (Moyle et al 2011) concluded that even though each imperiled species has its own combination of causes of decline, common stress factors are two: large-scale landscape changes (mainly invasive species, dams, agriculture and urbanization) and climate change. 62% of threatened fish in California are affected by climate change, especially those species that rely on flows of cool water (< 20C).

What did we find out/How are we doing?

NATIVE FISH CONSERVATION STATUS

Metric 1: State-wide conservation status

A recent state-wide fish status assessment as of December 31, 2010 was presented by Moyle et al (2011) and its results are presented here as a suggested metric to be evaluated over time within the global indicator of fish condition. The assessment results indicated that of 129 freshwater fishes native to California, four are globally extinct (39%) and three (2%) are extirpated from the state. In addition, 33 (26%) are endangered in the near future if present trends continue and 33 (26%) are vulnerable or threatened to be on a trajectory towards extinction if present trends continue. 34 species (26%) are in long-term decline or have small isolated populations but do not face extinction in the foreseeable future (near threatened). The remaining 22 species (17%) are of least concern (Figure 2).

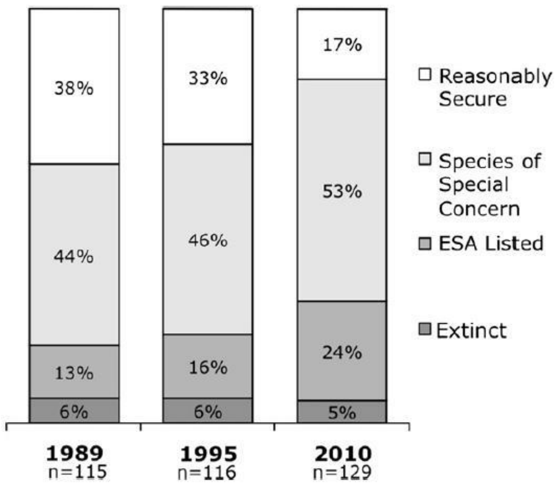


Figure 2. Status of the native fish of California (From Moyle et al 2011). (Note: The graph represents three different surveys presented here which show trends in time).

Currently, 31 species are formally listed as Endangered or Threatened under federal and/or state endangered species acts (ESA), compared to only 14 species that were formally ESA listed in 1989 (Moyle and Williams 1990). In addition, 7 species have gone extinct in the past 50 years. These official numbers show that California native fish fauna is in a rapid decline; however, the 2010 conservation status survey indicated that the decline is more severe than recognized (Moyle et al 2011).

Metric 2: Status of Key Fish Species

This metric was not evaluated for a specific species within this indicator report due to data availability. However, as explained in previous sections it is suggested for some key California fish species, including the Central Valley Chinook Spring-Run Salmon, Coho Salmon, Delta Smelt, Sacramento Perch.

FISH COMMUNITY COMPOSITION

Metric 1: Percentage of native fish richness expected

The composition of current fish communities was compared with historical/expected composition for all HUC 12 watersheds that contain historic richness data for California. The southern Central Valley (Tulare Basin), portions of inland Southern California, and the desert regions near the Colorado River received score between 0 and 20 (red color, Figure 6) because of the absence or near-absence of native fish species. A full list of the species in this analysis is available in Table 1.

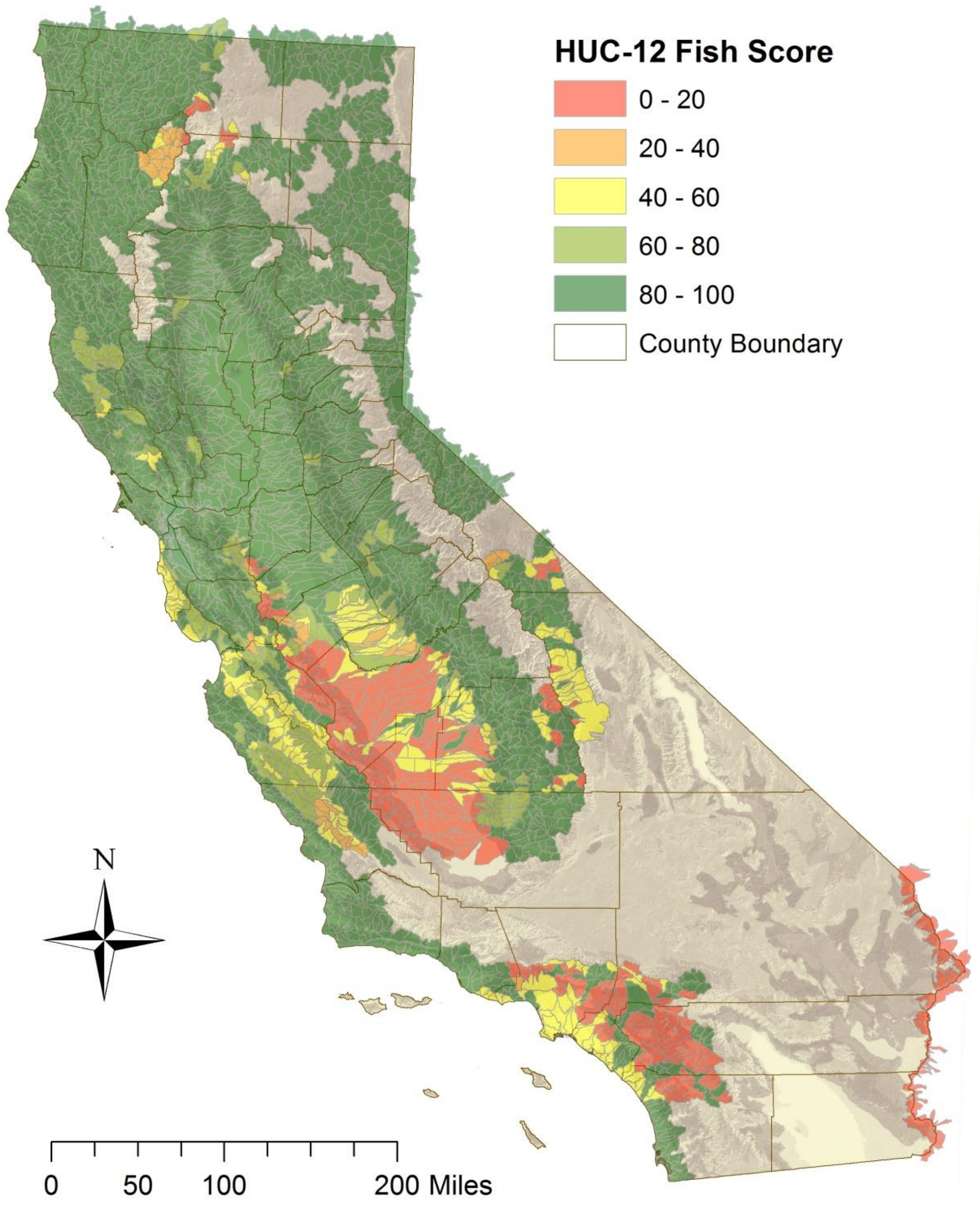


Figure 3. Richness scores for all HUC 12 watersheds that contain historic richness data for California

Table 1. Species with current range in California included in analysis

Arroyo chub	Lost River sucker
Bigeye marbled sculpin	Lower Klamath marbled sculpin
Blue chub	McCloud River redband trout
California golden trout	Modoc sucker
Central California roach	Monterey hitch
Central Coast coho salmon	Monterey roach
Central Valley fall Chinook salmon	Mountain sucker
Central Valley late fall Chinook salmon	Mountain whitefish
Chum salmon	Northern (Pit) roach
Clear Lake hitch	Northern green sturgeon
Clear Lake roach	Owens speckled dace
Coastal cutthroat trout	Owens sucker
Delta smelt	Pacific lamprey
Eagle Lake rainbow trout	Paiute cutthroat trout
Eagle Lake tui chub	Pit-Klamath brook lamprey
Eulachon	Red Hills roach
Goose Lake lamprey	Reticulate sculpin
Goose Lake redband trout	Riffle sculpin
Goose Lake sucker	River lamprey
Goose Lake tui chub	Sacramento hitch
Gualala roach	Sacramento perch
Hardhead	Sacramento pikeminnow
Kern brook lamprey	Sacramento tule perch
Kern River rainbow trout	Santa Ana speckled dace
Klamath largescale sucker	Southern Oregon Northern California coast coho salmon
Klamath Mountains Province summer steelhead	Southern Oregon Northern California coast fall Chinook salmon
Klamath Mountains Province winter steelhead	Tahoe sucker
Klamath River lamprey	Tomales roach
Lahontan cutthroat trout	Upper Klamath marbled sculpin
Lahontan lake tui chub	Upper Klamath-Trinity fall Chinook salmon
Lahontan redside	Upper Klamath-Trinity spring Chinook salmon
Lahontan speckled dace	Western brook lamprey
Long Valley speckled dace	White sturgeon
Longfin smelt	

Table 2. Species with gains in current range in California included in analysis.

Arroyo chub	Lower Klamath marbled sculpin
Bigeye marbled sculpin	McCloud River redband trout
California golden trout	Modoc sucker
Central California roach	Mountain sucker
Chum salmon	Mountain whitefish
Clear Lake hitch	Northern (Pit) roach
Clear Lake roach	Northern green sturgeon
Coastal cutthroat trout	Owens speckled dace
Delta smelt	Owens sucker
Eagle Lake rainbow trout	Pacific lamprey
Eagle Lake tui chub	Paiute cutthroat trout
Eulachon	Pit-Klamath brook lamprey
Goose Lake lamprey	Reticulate sculpin
Goose Lake redband trout	Riffle sculpin
Goose Lake sucker	River lamprey
Goose Lake tui chub	Sacramento hitch
Gualala roach	Sacramento perch
Hardhead	Sacramento pikeminnow
Kern brook lamprey	Sacramento tule perch
Klamath Mountains Province winter steelhead	Santa Ana speckled dace
Lahontan cutthroat trout	Southern Oregon Northern California coast coho salmon
Lahontan lake tui chub	Tahoe sucker
Lahontan redside	Upper Klamath marbled sculpin
Longfin smelt	Western brook lamprey
Lost River sucker	White sturgeon

Table 3. Species with losses in current range in California included in analysis.

Arroyo chub	Long Valley speckled dace
California golden trout	Monterey roach
Central Coast coho salmon	Northern (Pit) roach
Central Valley fall Chinook salmon	Owens speckled dace
Central Valley late fall Chinook salmon	Owens sucker
Coastal cutthroat trout	Pacific lamprey
Colorado pikeminnow	Sacramento hitch
Goose Lake tui chub	Sacramento perch

Hardhead	Sacramento pikeminnow
Kern River rainbow trout	Sacramento tule perch
Klamath Mountains Province summer steelhead	Santa Ana speckled dace
Klamath Mountains Province winter steelhead	Southern Oregon Northern California coast coho salmon
Klamath River lamprey	Tomales roach
Lahontan cutthroat trout	Upper Klamath-Trinity fall Chinook salmon
Lahontan lake tui chub	Upper Klamath-Trinity spring Chinook salmon

Metric 4: Proportion of non-native species

This metric was not evaluated within this indicator report due to incomplete data availability in the PISCES database (our data source). However, as explained in previous sections it is suggested for future analysis of fish and watershed condition.

Temporal and spatial resolution

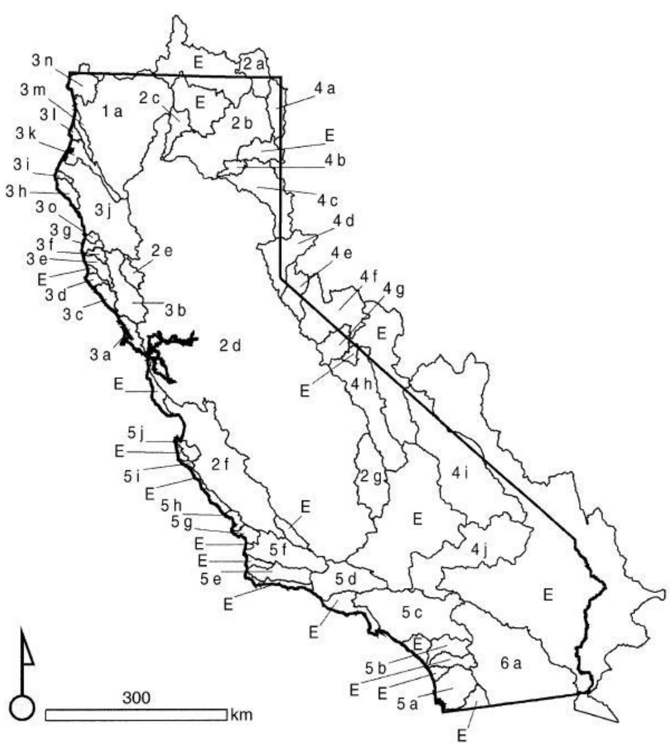


Figure 7. Spatial Resolution

How sure we are about the findings (things to keep in mind)

NATIVE FISH STATUS

The quantitative protocol used for the fish conservation status assessment (Moyle et al 2011) includes a variable (external to the status assessment) that evaluates the certainty of the score status per species. The reason is that the amount and reliability of information varied among species, so a certainty index was created based on a 1-4 scale : 1 –based on expert opinion, 2 – based on expert opinion with limited data and reports, 3- based on extensive information found from agency reports, 4 – based on reports from multiples sources including peer-reviewed literature.

OBSERVED OVER HISTORIC SCORE

We did not have current and historic ranges for all fish species in CA, nor all HUC 12 watersheds in the CA region. In addition, the value for current richness in the PISCES database does not always match the number of species listed in the species assemblage.

Several species showed "gains" or "losses" in richness across all HUC 12 watersheds in this analysis. These are listed in Table 3 and 4, respectively.

Technical Information

Data Sources

All fish data, spatial or otherwise, for the observed over historic species ranges come from the Pisces Database – University of California, Davis.

This is a comprehensive database that is compiling California native and non-native fish data from different sources and public institutions. Up to date, Pisces' main sources of information are the long-term monitoring databases resulting from the studies of Prof. Peter Moyle in different watersheds throughout the state.

Data Transformations and Analysis

Data were downloaded from the Pisces database as spatial files for import into ArcGIS. We used Arc GIS spatial software to display the historic and observed ranges of native fish species throughout California. To illustrate effects on individual watersheds we used Hydrologic Unit Codes representing the smallest sub-watershed level (HUC 12).

Ranges were downloaded for all species in the Pisces database that had both historic and observed range data. These range maps were combined to create one database with columns included for range type, species, and species richness. This resulted in multiple species and range types for many of the HUC 12 watersheds in California.

Table 4. Data Analysis

Range Type	Frequency
Historic and Observed	312
Observed	2594
Grand Total	**2906**

To create the observed over historic score, we simply divided the frequency of HUC 12 watersheds for each type. Ratios greater to or equal to 1 were given a score of 1, and the resulting ratios multiplied by 100 to give a range of 0-100.

There were several assumptions made in determining the results of our analysis. First, there are several species that have seasonal ranges. We used the full extent of the range, independent of the season. Also, subspecies were treated separately, i.e. as different species. This approach added to the species richness for both historic and observed distributions.

Sub-Appendix 1.

Table 2

Scoring rubric for seven metrics used to evaluate status of native freshwater fishes of California. Final status score is the average score of all seven metrics.

1A. Area occupied: resident fish
1. 1 watershed/stream system in California only based on watershed designations in Moyle and Marchetti (2006)
2. 2–3 watersheds/stream systems without fluvial connections to each other
3. 3–5 watersheds/stream systems with or without fluvial connections
4. 6–10 watersheds/stream systems
5. More than 10 watersheds/stream systems

1B. Area occupied: anadromous fish
1. 0–1 apparent self-sustaining populations
2. 2–4 apparent self-sustaining populations
3. 5–7 apparent self-sustaining populations
4. 8–10 apparent self-sustaining populations
5. More than 10 apparent self-sustaining populations

2. Estimated adult abundance
1. ⩽500
2. 501–5000
3. 5001–50,000
4. 50,001–500,000
5. 500,000+

3. Dependence on human intervention for persistence
1. Captive broodstock program or similar extreme measures required to prevent extinction
2. Continuous active management of habitats (e.g., water addition to streams, establishment of refuge populations, or similar measures) required
3. Frequent (usually annual) management actions needed (e.g., management of barriers, special flows, removal of alien species)
4. Long-term habitat protection or improvements (e.g., habitat restoration) needed but no immediate threats need to be dealt with
5. Species has self-sustaining populations that require minimal intervention

4. Environmental tolerance under natural conditions
1. Extremely narrow physiological tolerance in all habitats
2. Narrow physiological tolerance to conditions in all existing habitats or broad physiological limits but species may exist at extreme edge of tolerances
3. Moderate physiological tolerance in all existing habitats
4. Broad physiological tolerance under most conditions likely to be encountered
5. Physiological tolerance rarely an issue for persistence

5. Genetic risks/problems
1. Genetic viability reduced by fragmentation, genetic drift, and isolation by distance, owing to very low levels of migration, and/or frequent hybridization with related fish
2. As above, but limited gene flow among populations, although hybridization can be a threat
3. Moderately diverse genetically, some gene flow among populations; hybridization risks low but present
4. Genetically diverse but limited gene flow to other populations, often due to recent reductions in connectivity
5. Genetically diverse with gene flow to other populations (good metapopulation structure)

6. Vulnerability to climate change
1. Vulnerable to extinction in all watersheds inhabited
2. Vulnerable in most watersheds inhabited (possible refuges present)
3. Vulnerable in portions of watersheds inhabited (e.g., headwaters, lowermost reaches of coastal streams)
4. Low vulnerability due to location, cold water sources and/or active management
5. Not vulnerable, most habitats will remain within tolerance ranges

7. Anthropogenic causes of decline
1. 1 or more causes rated critical or 3 or more threats rated high–indicating species could be pushed to extinction by one or more threats in the immediate future (within 10–25 years)
2. 1 or 2 causes rated high; species could be pushed to extinction in the foreseeable future (within 50 years)
3. No causes rated high but 5 or more threats rated medium; no single threat likely to cause extinction but all threats in aggregate could push species to extinction in the next century
4. 1–4 causes rated medium; no immediate extinction risk but taken in aggregate causes reduce population viability
5. 1 medium, all others low; known causes do not imperil the species

Sub-Appendix 2.

Baseline fish community composition in main watershed regions in California, by 2000.

Watershed	Watershed code	Original native fish diversity	Nonnative fish diversity
Lower Klamath River	1a	20	14
Goose Lake	2a	8	11
Pit River	2b	13	15
McCloud River	2c	7	4
Sacramento/San Joaquin River	2d	29	41
Clear Lake	2e	14	18
Monterey	2f	19	20
Kern River	2g	4	7
Tomales	3a	11	7
Russian River	3b	21	19
Gualala River	3c	8	0
Garcia River	3d	8	0
Navarro River	3e	9	0
Big River	3f	8	0
Noyo River	3g	5	0
Matolle River	3h	8	0
Bear River	3i	9	0
Eel River	3j	14	10
Mad River	3k	14	8
Little	3l	9	0
Redwood	3m	12	6
Smith River	3n	12	0
Ten Mile Creek	3o	7	0
Surprise Valley	4a	3	2
Eagle Lake	4b	5	2
Susan River	4c	8	7
Truckee River	4d	8	15
Carson River	4e	8	14
Walker River	4f	8	13
Mono Lake	4g	0	6
Owens River	4h	4	14
Amargosa River	4i	3	2
Mojave River	4j	1	23
San Diego	5a	7	26
Santa Margarita	5c	9	12
Los Angeles	5d	12	34
Santa Clara	5e	7	24
Santa Inez	5f	6	16
Santa Maria	5g	7	8
San Luis Obispo	5h	7	8
Morro	5i	8	10
Big Sur	5j	6	0
Carmel River	5k	5	12
Salton Sea	6a	1	24

6. Public Support for Water Measures

Polling of public support for bond investments and public perception of problems associated with water management.

Sustainability Goal:

Goal 1. Manage and make decisions about water in a way that integrates water availability, environmental conditions, and community well-being for future generations.

Sustainability Domain:

Public understanding and support for public policies and investments in water system is an important part of water sustainability, supporting the domain of Adaptive and Sustainable Management.

What is it?

Public awareness and perceptions of the role water plays in their lives and in the environment can affect how people vote to support candidates, taxes/assessments, and bond issues. It is both important to keep the public informed to support democracy and to track their knowledge and perceptions in order to develop policies and management actions.

A common practice among sustainability indicator systems is to measure public awareness and support for environmental protection. This can be measured in several ways, including knowledge of environmental issues, expenditures to support the environment, and voting for pro-environment measures. When people have knowledge, they are more likely to take demonstrable action in support of environmental protection.

The public expects clean and readily-available water. Their expectation is usually that this public resource will be provided through state and local agencies, using public funds and based on policies that maintain the resource in trust. Measuring public understanding and support for water management and water policies is one proxy measure for how well state and local agencies are stewarding public trust resources.

The indicator relates to two proposed indicators in the Sustainability Indicators Framework:

Level of support or opposition for environmental measures, such as statewide bonds and local environmental regulation (% of population).

When voters show up to support (or disapprove) environmental measures, they are consciously changing public direction and potentially charging themselves through taxation or fees. When votes are for environmental measures, this is a direct measure of public support for stewardship and protection.

Public awareness of source water protection

A common practice among sustainability indicator systems is to measure public awareness and support for environmental protection. This can be measured in several ways, including knowledge of environmental issues, expenditures to support the environment, and voting for pro-environment measures. When people have knowledge, they are more likely to take demonstrable action in support of environmental protection.

Why is it important?

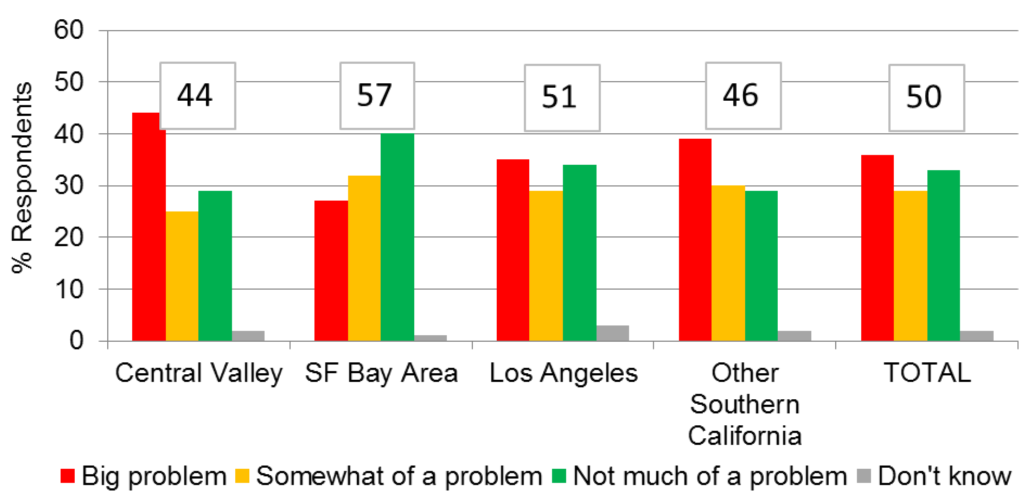
A high proportion of the state's water policies and management actions revolve around public-obligation bond measures to repair or build infrastructure. In order for these actions to be supported, the public needs to both understand current conditions and feel like actions intended to mitigate risks address their concerns. For issues that seem contentious (e.g., climate change impacts) or that may be particularly expensive, public education and polling may drive timelines and potential solutions for these issues.

What did we find out/How are we doing?

Public support for state investments in water systems, and similar issues, has remained moderate since 2006 and opposition to investing and making changes has declined. Although public support has not declined during the expansion of the bonds approach and the recession, it is worth noting that support is consistently less than 50% and a large proportion of people have a middle of the road view of conditions and tepid support for investments.

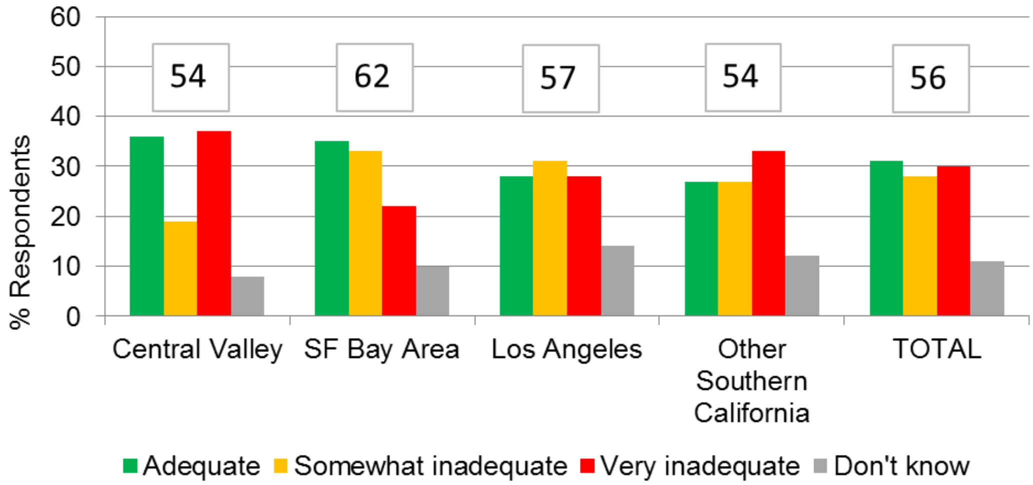
1. Problems with current water supply (December, 2012)

Although no statistical analysis was carried out, it seems that there are regional differences in people's perceptions about current water supply, especially when comparing the Central Valley with the San Francisco Bay Area. The overall score of 50 indicates that many in the public are concerned about current water supply.



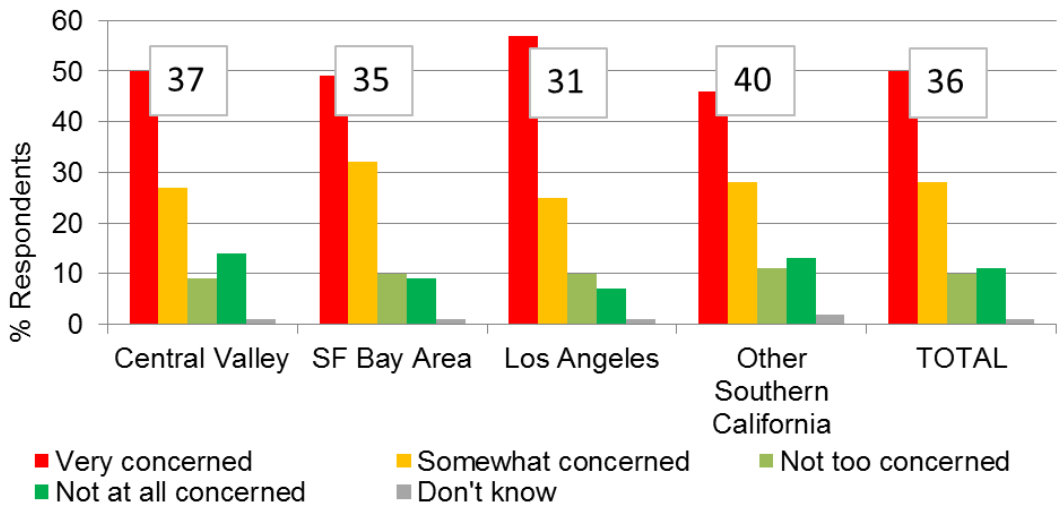
2. Problems with future (10 years) water supply (December, 2009)

Similar to the situation with current water supplies (1), many members of the public are concerned about future water supplies, with potential differences among regions. The overall score is better than for current water supplies, but indicates that many in the public are concerned about their future water supplies.



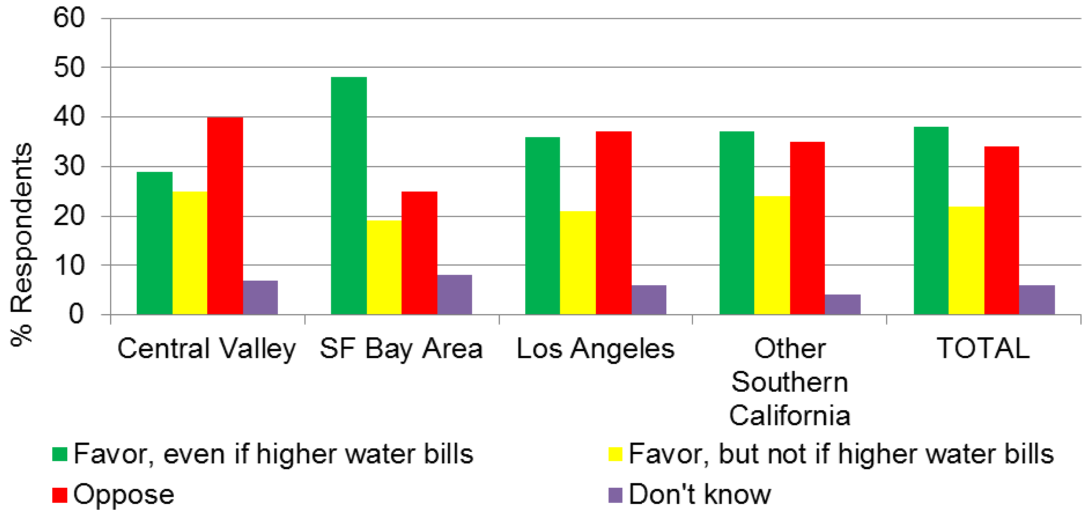
3. Risk of severe droughts as a result of climate change/global warming (July, 2011)

Across all regions of the state, members of the public are concerned about the potential impact of climate change on drought conditions, where severe droughts can limit water availability to communities, agriculture, and natural systems. The overall score (36) is fairly low, indicating that most of the public is concerned about future water conditions due to climate change.



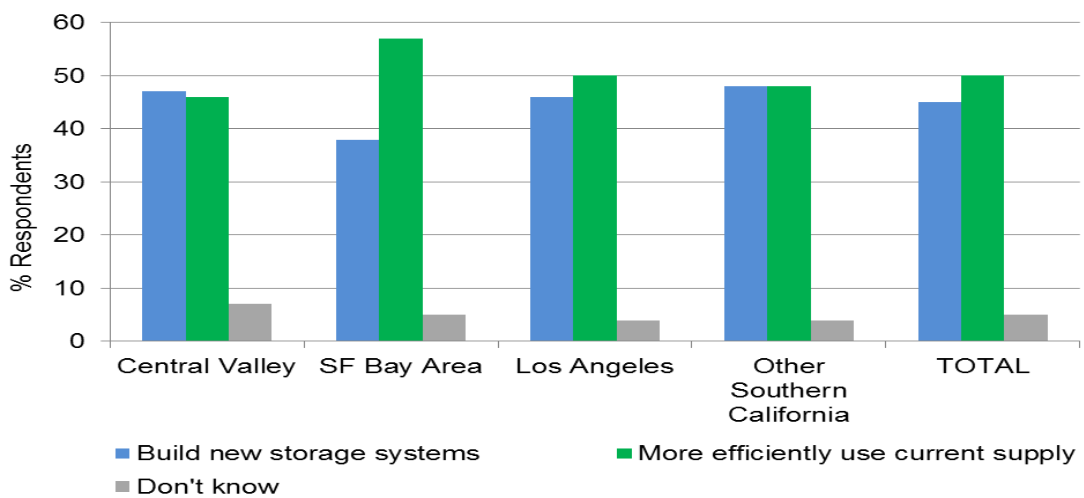
<u>*4. Management: Increase spending to improve conditions for native fish (December, 2012)*</u>

No score was calculated for this metric. A majority of those surveyed favored increased spending to protect and restore fish habitat, with inter-regional differences in responses, especially between the Central valley and the Bay Area. From a conservation perspective, one way to score this metric would be to calculate the score as 100 - % opposed, which for the total respondent pool would give a score of 66.



<u>*5. Management: Water supply priorities for 2025 (December, 2012)*</u>

No score was calculated for this metric. 50% of those surveyed favored more efficient use of current supplies over construction of new water storage systems, with inter-regional differences in responses, especially between the Central valley and the Bay Area. From an economic perspective, one way to score this metric would be to calculate the score as 100 - % in favor of new storage, which for the total respondent pool would give a score of 55.



Basis of calculation and use

Respondents to the surveys on water issues were asked to state their preferences on scales that ranged from strong concern to no concern for potential risks and strong support to disapproval for particular water policies. In general, the desired condition was assumed to be low or no concern about risks to approval for water-protecting policies to mitigate risks to water supply and natural systems.

Who else uses it?

- **Waikato Regional Council** (NZ, http://www.ew.govt.nz/Environmental-information/Environmental-indicators/)
- **State of the Watershed Reporting Framework** (Canada, http://www.swa.ca)

What is the target or desired condition?

Three metrics were scored for condition: 1) Problems with current water supply; 2) Problems with future water supply; and 3) Risk of drought because of climate change.

1) **Problems with current water supply:** The desired target condition was that the public did not think that there were problems with their water supply. The undesired condition was that the public thought there were big problems with the current water supply. Scores were calculated using the following equation: Score = 100-(% respondents stating "big problem" + 0.5 X % respondents stating "somewhat of a problem")
2) **Problems with future water supply:** The desired target condition was that the public thought that there their future water supply would be adequate. The undesired condition was that the public thought their future water supply would be inadequate. Scores were calculated using the following equation: Score = 100-(% respondents stating "very inadequate" + 0.5 X % respondents stating "somewhat inadequate")
3) **Risk of severe droughts because of climate change:** The desired target condition was that the public were not concerned about severe droughts in response to climate change/global warming. The undesired condition was that the public was very concerned about severe droughts in response to climate change/global warming. Scores were calculated using the following equation: Score = 100-(% respondents stating "very concerned" + 0.5 X % respondents stating "somewhat concerned")

What can influence or stress condition?

As people become aware of problems and policies related to water sustainability they are more likely to have an opinion. This is relevant to agencies and policy-makers because they may require (e.g., for bond measures) or appreciate public support. One phenomenon that may be influential on the outcomes of specific questions or polls on water sustainability is recent and severe events such as drought, flooding, and exceptional die-offs of valued fish, such as salmon.

Temporal and spatial resolution

The PPIC conducts periodic surveys of public perceptions of various social, economic and environmental conditions and policies. Specific questions about water are present in public surveys several times a year, allowing an approximately annual assessment of public perceptions about water supply, quality, policies, and other conditions. Individual responses are at the scale of the respondents, but responses are typically aggregated to regions (e.g., Central Valley or Los Angeles).

Technical Information

Data Sources

PPIC (http://www.ppic.org/main/datadepot.asp). Used the "Statewide Survey Database Search" tool with the keyword "water" to find survey data related to water sustainability. "All manuscripts, articles, books, and other papers and publications using Institute's data should reference Mark Baldassare as Survey Director and the Public Policy Institute of California as the source of the data, and should acknowledge that PPIC bears no responsibility for the interpretations presented or conclusions reached based on analysis of the data."

Data Transformations and Analysis

The survey responses reported by PPIC were used directly in scoring. In other words, if 75% of respondents preferred a certain category of action, then that % was used without modification.

7. Water Footprint

The consumption of water to make goods and services for an individual, industry, or geographic area.

Sustainability Goal and Objective:

Goal 1. Manage and make decisions about water in a way that integrates water availability, environmental conditions, and community well-being for future generations.

Sustainability Indicator Domain:

Water Supply Reliability = The availability or provision of water of sufficient quantity and quality to meet water needs for health and economic well-being and functioning.

What is it?

The water footprint is the sum of the water used directly or indirectly to produce goods and services consumed by humanity. Agricultural production accounts for most of global water use, but drinking, manufacturing, cooking, recreation, washing, cleaning, landscaping, cooling, and processing all contribute to water use (Hoekstra et al. 2011). In addition to these direct water uses, indirect uses such as water impacted by pollutants, chemical or temperature, contribute to the water footprint. The water footprint is a composite of water use indicators ("blue water", "green water" and "gray water") and is used here as an index of water sustainability. Blue water is the water that is retrieved from a natural source and managed (e.g., through a reservoir or pipes) before it used to make a good or service. Green water is naturally-occurring precipitation that plants use to grow (e.g., crop plants). Gray water is the water impacted by the discharge from production and is the sum of the water required to reduce pollutants to acceptable levels.

The Water Footprint Network developed a global water footprint standard that contains definitions and calculation methods for determining water footprints for different purposes and scales (Hoekstra et al., 2011). The assessment contains four steps: Setting goals and scope, water footprint accounting, water footprint sustainability assessment, and water footprint response formulation. There are different types of water footprints: the water footprint of a product, consumer, community, national consumption, business, and any geographic area. The level of detail needed for data as well as the frequency of measurements depends on the spatial scale assessed.

Why is it Important?

By measuring and understanding the many ways that Californians use water, whether it is through pipes or from food production, we can reduce the risks and uncertainties associated with certain ways of using water in production and improve our water sustainability. As global climate change occurs, different parts of the world will be affected differently, which will affect the reliability of receiving imported goods and services. This will in turn affect water management in California as domestic sources either make up for shortfalls in imports through increased production, or reduce their water use due to international trade pressures. Calculating and using the water footprint in water planning and assessment is an acknowledgement that we participate both in global trade and in one water cycle.

WF and Food Production

Coupling virtual water with economic information describing the production value of a crop can further strengthen agricultural water management. 'Water economic productivity', expressed in terms of crop market value per cubic meter of water used, has been derived, for example, for the Guadiana River Basin, Spain (Aldaya et al., 2010). That study distinguished 'low virtual water, high economic value' crops from 'high virtual water, and low economic value' alternatives, in a semi-arid region characterized by irrigated agriculture. The findings showed that 'high virtual water, low economic value' crops such as cereals are widespread in the region, in part due to the legacy of earlier subsidies. The study concludes that the agricultural sector will need to modify its water use greatly if it is to achieve significant water savings and environmental sustainability.

WF and Supply Chain Vulnerability

Water Footprint assessment has been recognized by various corporation as important in understanding the vulnerability of their supply chains to the changing availability of water to make products that feed into their supply chain. Because most water footprint assessments have not addressed the environmental impacts of water use, corporate organizations are increasingly moving away from water foot-printing alone towards water stewardship approaches. The UK retailer, Marks & Spencer, uses a three-tiered approach, drawing on the water footprint methodology:

- Tier 1: (**standards**) Marks & Spencer defines criteria that their suppliers have to meet.
- Tier 2: (**risk**) Marks & Spencer tries to use information on water risk in its supply chains to identify which products are from areas at risk of water stress. This has included using both Water Footprint Assessment and other tools.
- Tier 3: (**influence**) using the information on water risk in their supply-chain, Marks & Spencer identifies which suppliers to target with its water stewardship approach. Marks & Spencer is not simply targeting suppliers located in areas at risk of water stress — after all, a supplier may be working sustainably even if located in a high risk area. Sustainable suppliers are given an award for sustainable practice. Marks & Spencer is also working with WWF and the Food Ethics Council to foster stakeholder engagement.

WF Based on Income

Water Footprint is a useful meme to characterize both our dependence on water and our impacts on water systems. Consumption of goods and services requires delivery of water through natural and engineered pathways and return of wastewater to the environment. The greater the consumption, the greater the water footprint. Because there is variation in income in California and the US, as there is elsewhere in the world, it is useful to estimate water footprint using income classes as one way to control for this variation. The Water Footprint Network has developed an online calculator that estimates the water footprint based on income (http://www.waterfootprint.org/?page=cal/waterfootprintcalculator_indv; Mekonnen, 2009).

A higher water footprint is both a greater impact on world water systems and a sign of vulnerability. Maintenance of a high water footprint may not be sustainable in a water-constrained world. Meat-based diet and higher income classes in the study area both had greater water footprints than the county averages and global averages. These lifestyles may become less sustainable with increased water limitations, or, if maintained, put unsustainable strain on water limited systems.

What is the target or desired condition?

The water footprint has been calculated for most countries, including the US, and recently for California. The average footprint for someone in California is about 1,500 gal/day (Fulton et al., 2012). This is slightly less than the water footprint of the average US resident of about 1,600 gal/day (Mekonnen and Hoekstra 2011) and greater than the global average of about 750 gal/day scoring approach used states that T The best score (100) is for water footprints that are less than the global average and sets a score of 0 at the largest global water footprint (Bolivia, 3,500 gal/day).

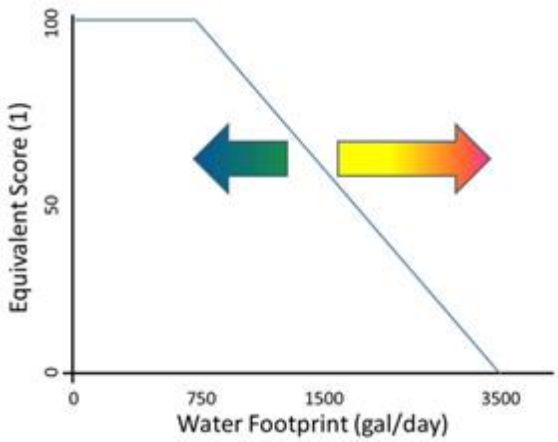


Figure 1. Scoring relationship for the water footprint.

What can influence or stress condition?

The water footprint of each person is based on summing the amount of "virtual water" embedded in the goods and services consumed (Hoekstra, 2012). Diet, income, consumption patterns, energy use, and other personal preferences and activities all affect individual water footprint. Thus, individual lifestyle choices are the most influential on water footprint.

In a geographic area, like a state, the water footprint of consumption depends on the aggregate of individual consumption and of production depends on the water use to make goods and services that are used within the area, or exported. The water footprint of the area does not include exported goods. The water use for goods and services produced within or outside (and imported into) an area defines the water footprint of the area. Thus, the water use decisions of producers and trade/import decisions of product providers will be most influential on water footprint.

Water availability and competition among users of limited water sources are the most influential on the source and type of water used to make goods and services and whether or not the goods and services will be available for export. Climate change and population growth are thought to be very influential factors in water stress and competition in the future, which will influence the size and composition (product variety) of future peoples' water footprint.

What did we find out/How are we doing?

California imports over two-thirds of its virtual water through products made elsewhere in the world, including other states ("External Water Footprint", Figure 2). This is quite a different story from 20 years ago, when Californians consumed roughly the same proportion (2/3) from products made in California ("Internal Water Footprint", Figure 2). This means that California is becoming increasingly dependent upon goods from other states and countries and therefore dependent upon water availability and management in these source-places. Although this situation may not be inherently good or bad, it does raise the possibility that California is becoming more vulnerable to the economic, political, and environmental conditions in other parts of the country and the world. As water becomes more valuable and potentially scarce, it is worth considering what this means.

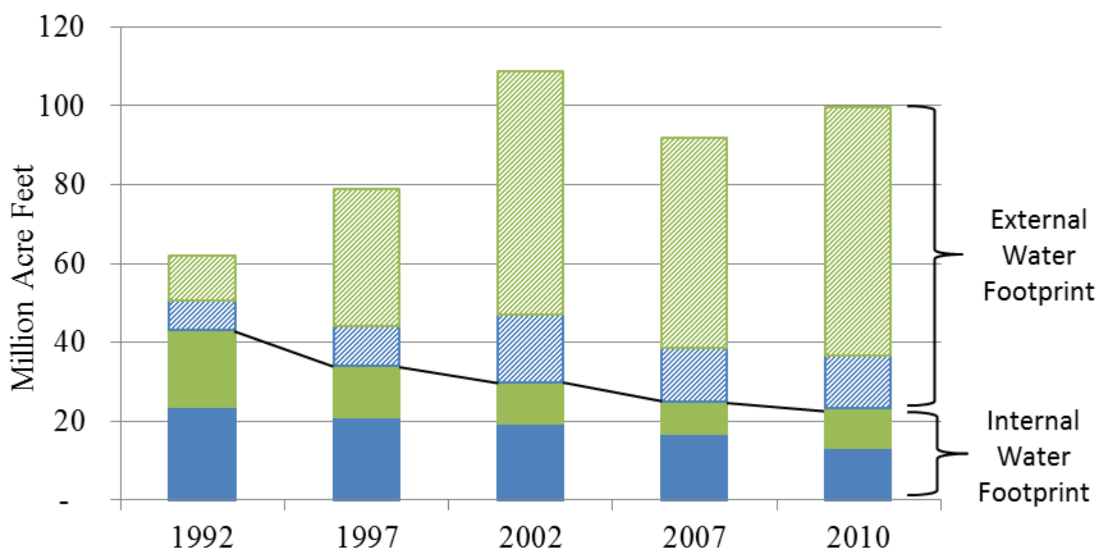


Figure 2. The total water footprint of goods and services consumed within California (million acre-feet) between 1992 and 2007. The blue part of each bar represents the blue water footprint and the green part of each bar represents the green water footprint. Hatching represents the "external water footprint", the virtual water from outside California, and the non-hatched areas represent the "internal water footprint", the virtual water from inside California.

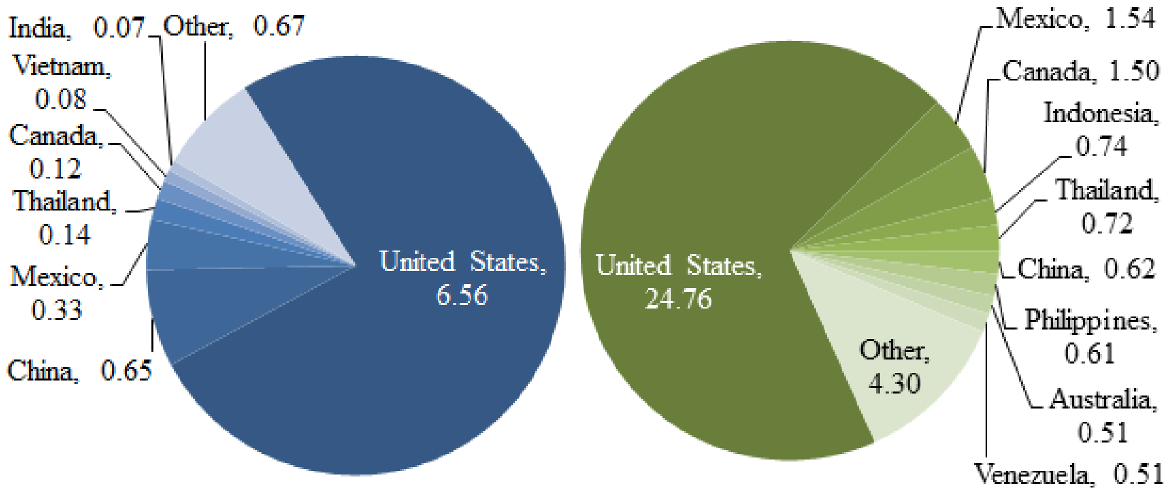


Figure 3. Blue and green WFs of products produced outside of California and imported, by origin (MAF).

The claim that we may be more vulnerable to international trends in water due to imports from around the country and the world, depends on which areas are important and how these areas may respond to at least future climatic conditions. Most of our virtual water in goods and services comes from other states (Figure 3). Roughly a quarter of the blue water footprint and a third of the green water footprint are in goods and services from other countries. Recently, the World Resources Institute (WRI) estimated the “baseline water stress” in countries around the world. Baseline water stress is a ratio of the amount of water withdrawn from a basin to the amount available from natural sources and imports. Based on the climatic conditions projected under different scenarios for greenhouse gas emissions, WRI estimated the BWS for every country, and regions within large countries, for the years 2025, 2050, and 2095. By 2025 (Figure 4a), most of the countries that California imports from (Figure 3) will potentially experience some water stress. By 2095, virtually all of the countries imported from and much of the mid-North American continent will potentially experience water stress (Figure 4b).

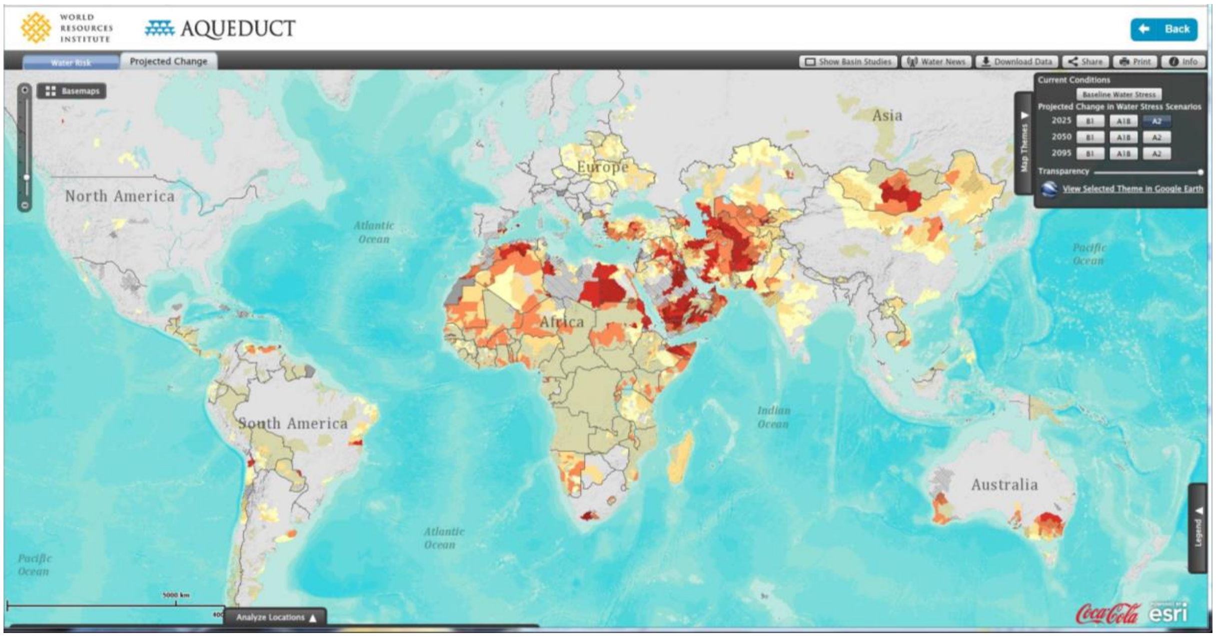


Figure 4a. Country/region-specific water stress by 2025. The darker the red color, the greater the potential stress because of pressures from demand and climate conditions/change.

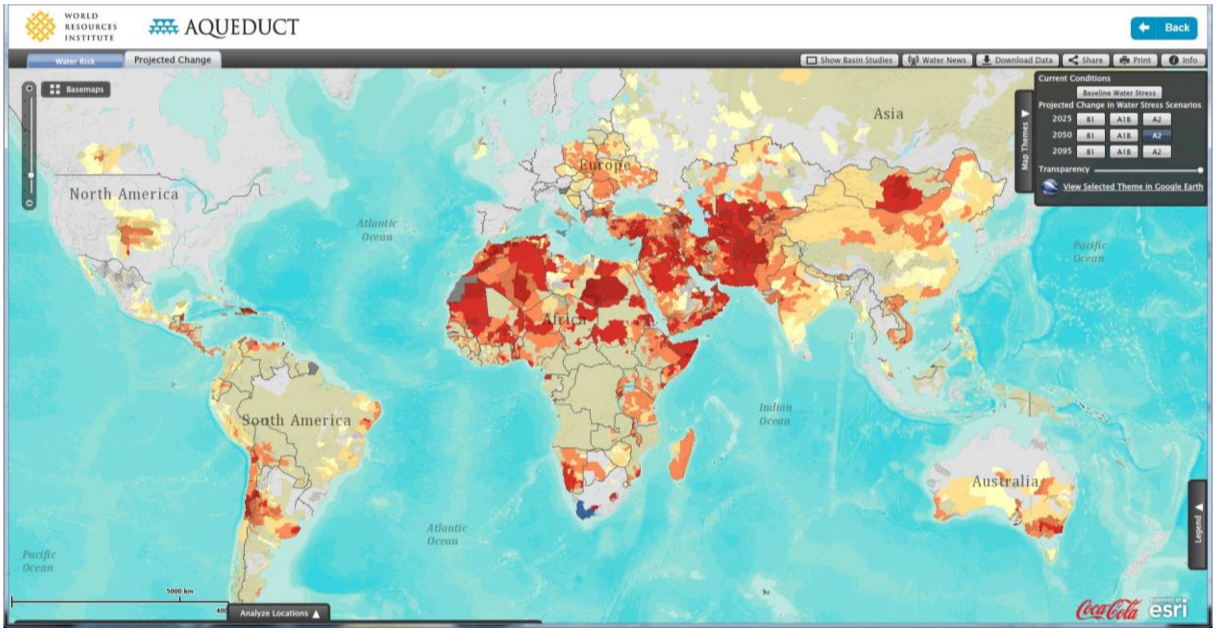


Figure 4b. Country/region-specific water stress by 2095. The darker the red color, the greater the potential stress because of pressures from demand and climate conditions/change.

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WF Based on Income

The Water Footprint Network has developed a calculator that estimates the water footprint based on income (http://www.waterfootprint.org/?page=cal/waterfootprintcalculator_indv; Mekonnen, 2009). This calculator was used in combination with Census Bureau data to estimate the water footprints for each of the 3 counties that make up the Santa Ana Watershed Project Authority (SAWPA) service region (Orange, Riverside, and San Bernadino). Median and mean household incomes in each county were the following: San Bernadino ($51,247 & $65,472), Riverside ($52,883 & $69,898), and Orange ($72,293 & $96,627). There was considerable variation around these values, with 4.5% to 6.9% of households occupying the lowest income category (<$10,000) and 2.9% to 9.4% of households occupying the highest category (>$200,000).

Relationship between Water Footprint and Income

Beyond a base level of consumption of goods and services, water footprint per capita increases linearly with income (Figure 5). Diet affected both baseline water footprint and rate of change in footprint with income. Vegetarian diet had the smallest water footprint and high-end meat consumption the largest. This is because of the investment of virtual water in grains used to grow animals for consumption, compared to the direct consumption of plant material.

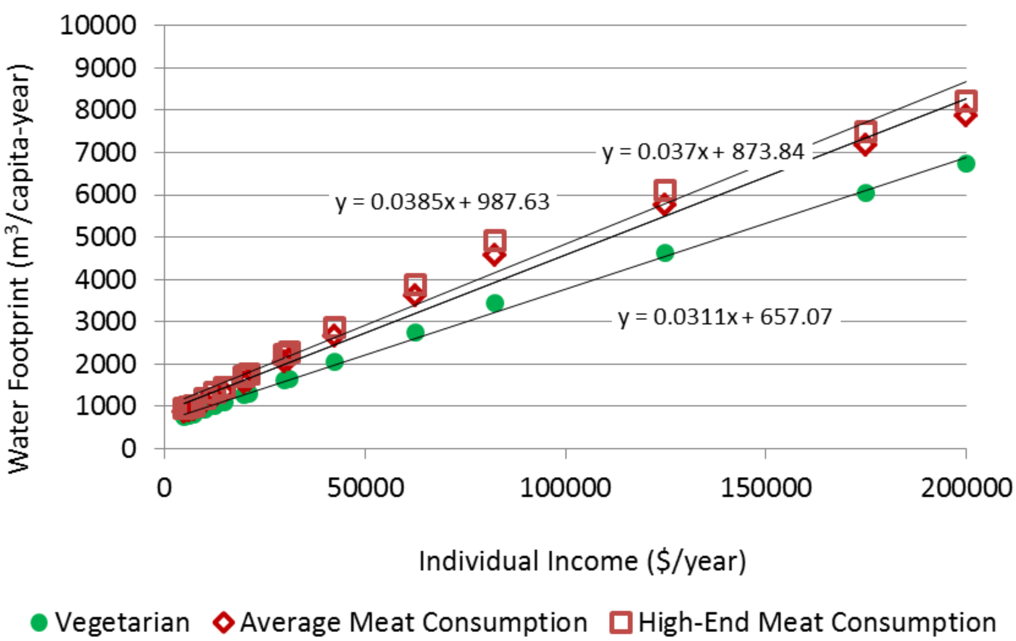


Figure 5. Rate of change in water footprint (m3/capita-year) with income ($/year) in the US.

Water Footprint and Income Class by County

The proportion of the total water footprint for a county associated with each income class was compared to the distribution of households associated with each income class (Figure 6).

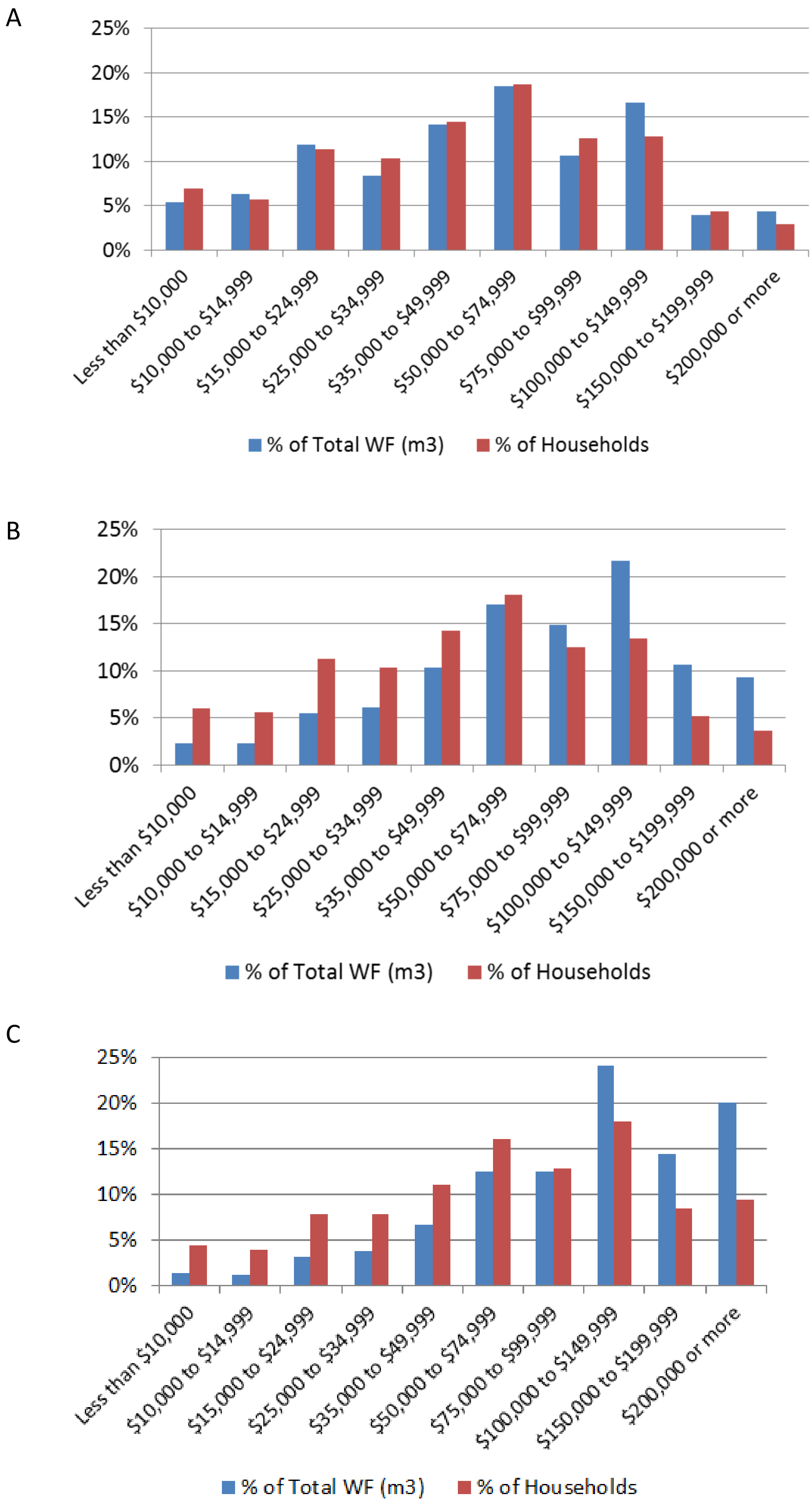


Figure 6. Proportion of people in each income class and proportion of total county water footprint associated with people in each income class for (A) San Bernadino, (B) Riverside, and (C) Orange Counties.

For San Bernadino County, the distribution of the water footprint by income class paralleled the distribution of income. For Riverside and Orange Counties, a greater proportion of the total county water footprint was associated with higher income classes. This is what would be expected because income distributions are skewed toward the high end, especially in Orange County where over half of the water footprint of the county is associated with the 3 household income classes >$100,000.

The average water footprint for 2011, weighted by income class, was 1,722 (San Bernadino), 2234 (Riverside), and 2,701 (Orange) m^3/capita-year. The total annual water footprint for each county based on income, number of households, and average number of people per household was: 3.42 x 10^9 m^3 (2.77 x 10^6 ac-feet, San Bernadino), 4.68 x 10^9 m^3 (3.80 x 10^6 ac-feet, Riverside), and 8.15 x 10^9 m^3 (6.61 x 10^6 ac-feet, Orange). The total water footprint for all 3 counties was 16.25 x 10^9 m^3 (13.18 x 10^6 ac-feet). The total water demand in 2010 through piped delivery systems from all sources for the Santa Ana Watershed Project Authority (SAWPA) was 1.36 x 10^6 ac-feet. Most of the population of the 3 counties resides within the SAWPA service area. Still, the water footprint was approximately 10 times the delivered water, by volume.

Temporal and spatial resolution

Calculations that form the basis of the water footprint may originate from years before the calculation is made. The data used to calculate California's water footprint (Fulton, 2012) were from 2005 and 2007. Thus the current framing of water footprint is probably generally accurate, but will still change over time. Individual water footprint can be calculated instantaneously, based on individual actions and choices. State or country-scale water footprint requires a different order of data and is likely to be possible to calculate annually.

Water footprint can be calculated per individual or household, using water-equivalents for the goods and services consumed by the individual or household. Aggregating the data from individual behavior to the scale of a state or country may not be possible. Calculating water footprint at these scales is possible, but involves using trade data and average behaviors across populations.

Technical Information

Data Sources

Fulton et al., 2012

Census 2011, American community Survey 2011 estimates of income by county (http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_11_1YR_S1902&prodType=table)

Water Footprint Network, Quick Water Footprint Calculator (http://www.waterfootprint.org/?page=cal/waterfootprintcalculator_indv)

Data Transformations and Analysis

WF Based on Income

The Census Bureau conducts surveys of community characteristics between the decadal population censuses, including household income. The Water Footprint Network includes a calculator of water footprint (Mekonnen, 2012) for different countries, based on diet, gender, and income. In this study, the water footprint was calculated using the WFN Quick Calculator for men and women eating vegetarian and meat-based diets. The distribution of water footprint for residents in different California counties was compared to the distribution of income within those counties. In addition, the effect of variation in diet was examined for the same distribution of incomes.

The income tables for specific California counties were downloaded from the “Fact Finder” tool on the Census Bureau website. These tables included proportion of population in each major household-income category (e.g., $50,000 to $74,999 per year), as well as basic statistics about household composition and total number of households.

The median value in each income category was calculated and used to estimate water footprint. The Quick Water Footprint Calculator was used to calculate water footprint based on gender, diet, and income. Three diet choices were provided: vegetarian, average meat consumption, and high-end meat consumption. For most calculations, “average meat consumption” was chosen to represent the most people. Because most households have two adults of opposite gender, the average of male and female water footprint was used and household income was assumed to represent two adults for the purposes of the water footprint calculation.

8. Water Quality Index (Impervious Surface)

Proportion of watershed covered with impervious surfaces, including pavement, buildings, and turf grass.

Sustainability Goal:

Goal 4. Improve quality of drinking water, irrigation water, and in-stream flows to protect human and environmental health.

Goal 5. Protect and enhance environmental conditions by improving watershed, floodplain, and aquatic condition and processes.

Sustainability Domain:

Water Quality = The chemical and physical quality of water to meet ecosystem and drinking water standards and requirements.

Ecosystem Health = The condition of natural system, including terrestrial systems interacting with aquatic systems through runoff pathways.

What is it?

Impervious surface is a measure of land cover. Water quality is affected by impervious surface development in watersheds. The more impervious surfaces are developed, the greater the chance that water quality will be degraded. It is derived from the National Land Cover Database using satellite imagery primarily from Landsat. Images are analyzed to reveal 16 land cover classes, including: water, developed, barren, forest, shrubland, herbaceous, planted/cultivated, and wetlands. Each land cover class is assigned a value for percent imperviousness based on a 30*30km resolution raster data set (USGS National Landcover Database). It is important to note that the percent impervious surface measurement is an estimate of imperviousness and not a direct measurement.

This indicator serves as a potential measure of impact of development on water quality, which can have secondary effects on drinking water quality and ecosystem health.

Basis of calculation and use

For the purposes of our analyses, we used impervious surface spatial data from the years 2001 and 2006. Spatial data for 1992 exists, but represents land cover classes, not impervious surface classifications. Methods exist for assigning impervious surface values for these land cover classes, but are location and scale dependent (e.g. Sacramento, San Diego river) and differ in accuracy (McMahon 2007).

One area of interest in the impervious surface indicator is the degree and pace of change over time. Currently data for percent impervious surface is available for 2001 and 2006, with the following important note for comparison between years from the NLCD website: "NLCD2001 Version 2.0 products must be used in any comparison of NLCD2001 and NLCD2006 data products." Furthermore, with regards to analysis using land cover and estimates in impervious surfaces, McMahon (2007) states the importance of resolution in data for informing land cover classes and developing models for impervious surfaces.

Why is it Important?

Impervious cover is a relatively easily measured metric that is valuable for watershed planners, storm water engineers, water quality regulators, economists, and stream ecologists (Schueler et al. 2009). It also acts as a measure of development and growth. Direct impacts of impervious surface include changes in land cover, hydrology, geomorphology, and water quality. Indirectly impervious surface impacts stream ecology, species richness, the economy, policy, and social well-being and human health. Bellucci (2007) cites multiple papers documenting the influence of land cover change on stream health, biotic integrity, and runoff; stating that increases in urbanization results in stormwater runoff that contributes to "flashier hydrograph, elevated concentrations of pollutants transported from impervious surfaces to streams, altered channel morphology, and reduced biotic integrity with dominance of more tolerant species."

What is the target or desired condition?

There are many estimates for a threshold of percent impervious surface, beyond which, measurable damage to stream systems is endured. Wang et al. (2003) estimate that between 6-11% impervious area, major changes in stream fish could occur. Fitzgerald et al. (2012) estimate increased sensitivity of stream ecosystems at between 5-10% impervious surface. Hilderbrand et al. (2010) suggest that within their study area, once percent impervious area reaches 15% a loss of nearly 60% of benthic macroinvertebrate taxa could occur. Schiff et al. (2007) calculate that above a critical level of 5% impervious surface, stream health declines. However, Allan (2004) makes the argument that although there is strong influence on stream health and land cover change, direct associations are complex and depend on anthropogenic and natural gradients, scale, nonlinear responses, and the difficulty in parsing out impacts from today and the past.

Thus, modeled predictions that utilize actual monitoring data for regions of interest, the stream indicators of greatest concern, the main land cover type , and represent a range of possible outcomes may be more realistic (Figure 1; Schueler et al. 2009). Furthermore, Schueler et al. (2009) mention several caveats regarding the use of impervious surface as an indicator for stream hydrology and health. These caveats include: consideration of watershed scale, problems with forming relationships between impervious surface and watersheds with major point source pollutant discharge or dams, importance in grouping watersheds within the same physiographic regions, and caution when applying models based on impervious surface when management practices are poor, especially in areas of low impervious cover (Schueler et al. 2009).

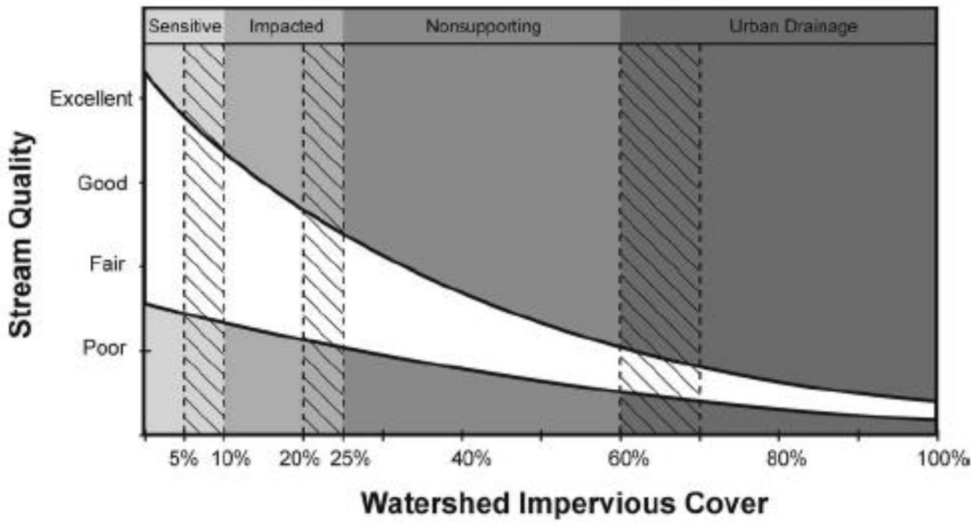


Figure 1. Conceptual model of impervious surface. This illustrates a range in stream quality as a result of impervious cover and the wide variability in stream indicator scores for impervious surface cover below 10% (Schueler et al. 2009).

What can influence or stress condition?

This indicator has a direct connection between stress and percent impervious surface. Therefore, development or conversion of land from "natural" to developed land is the only thing that could alter this condition. Furthermore, as stated previously, changes in land cover can indirectly affect geomorphology, water quality, and ecosystem health in terms of native species richness.

Climate change may influence the resulting scores for this indicator by altering the timing and amount of precipitation as well as from drought. Climate predictions result from a combination of scenarios and climate models that integrate estimates of greenhouse gas emissions and how the climate system will respond to these emissions. Therefore, variation within the predictions may result in different policy implications and actions. Furthermore, we are likely to see variation in the location, amount, and timing of precipitation rather than homogenous responses across the globe.

What did we find out/How are we doing?

Out of 4,637 watersheds, the mean percent impervious area for the state of California is 2.6%, with mean percent impervious area of hydrologic unit code (HUC) 12 watersheds ranging from 0-68.8% impervious area (Figure 2). The mean score and range of the Water Quality Index 90 and 29-100, respectively (Table 1; Figure 2).

Table 1. Summary statistics for mean impervious area and Water Quality Index (WQI) scores for the entire state of California (averaged among all watersheds with HUC 12 classification).

	Mean Percent Impervious	***WQI score***
Mean	2.63	0.90
Standard Error	0.12	0.00
Median	0.24	0.98
Mode	0.00	1.00
Standard Deviation	8.16	0.19
Range	68.76	0.71
Minimum	0.00	0.29
Maximum	68.76	1.00

California has been adding impervious surface to watersheds as populations have grown and urban areas have been actively expanded. Between 2001 and 2006, the vast majority of the state had no or very little (0 – 1%) impervious area development (Figure 4). Certain urban areas (e.g., Placer and Riverside counties) experienced up to 10% change in impervious cover (e.g., from 10% to 20%).

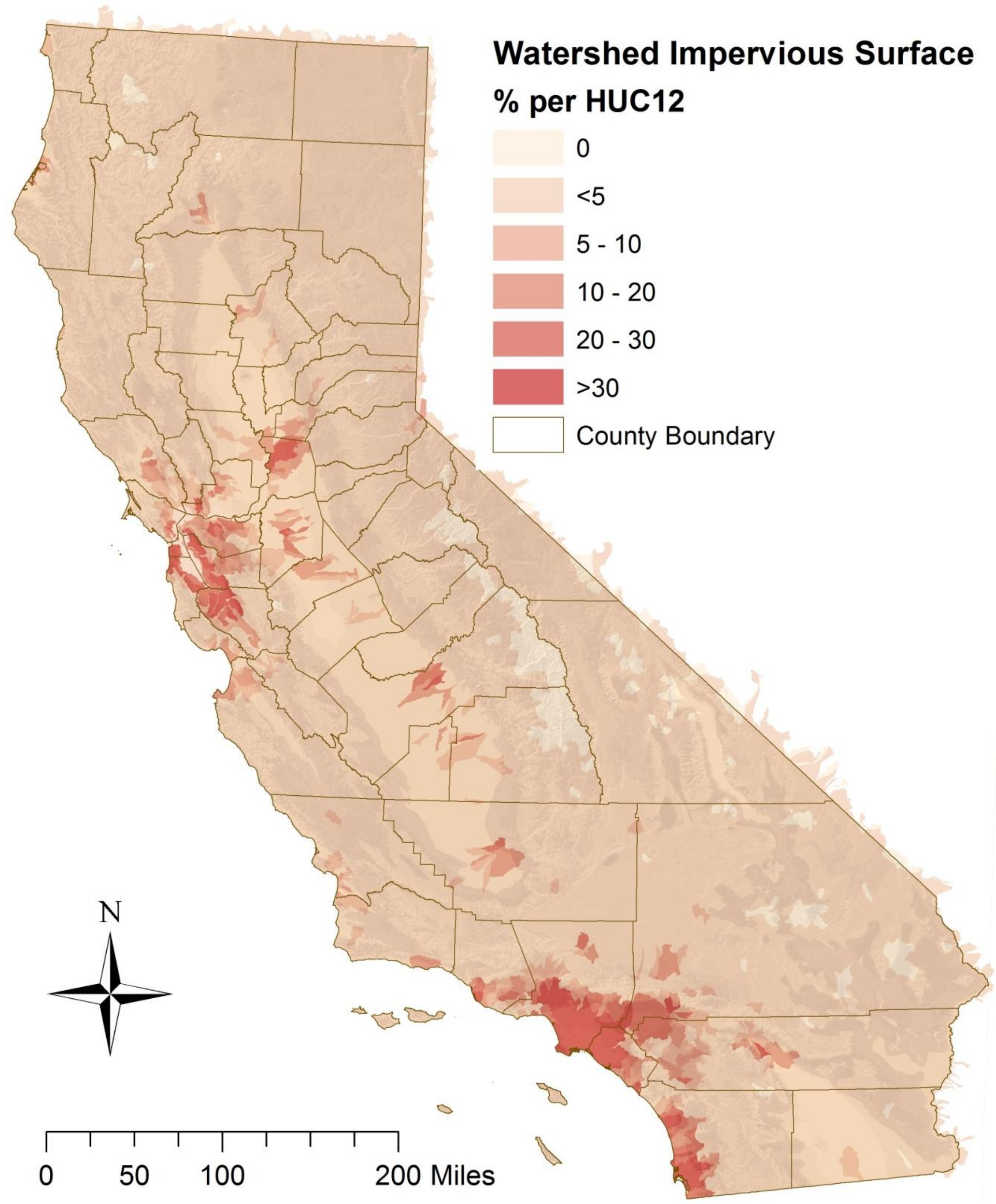


Figure 2. This map illustrates the mean percent impervious cover for each watershed with the hydrologic unit code classification of "HUC12".

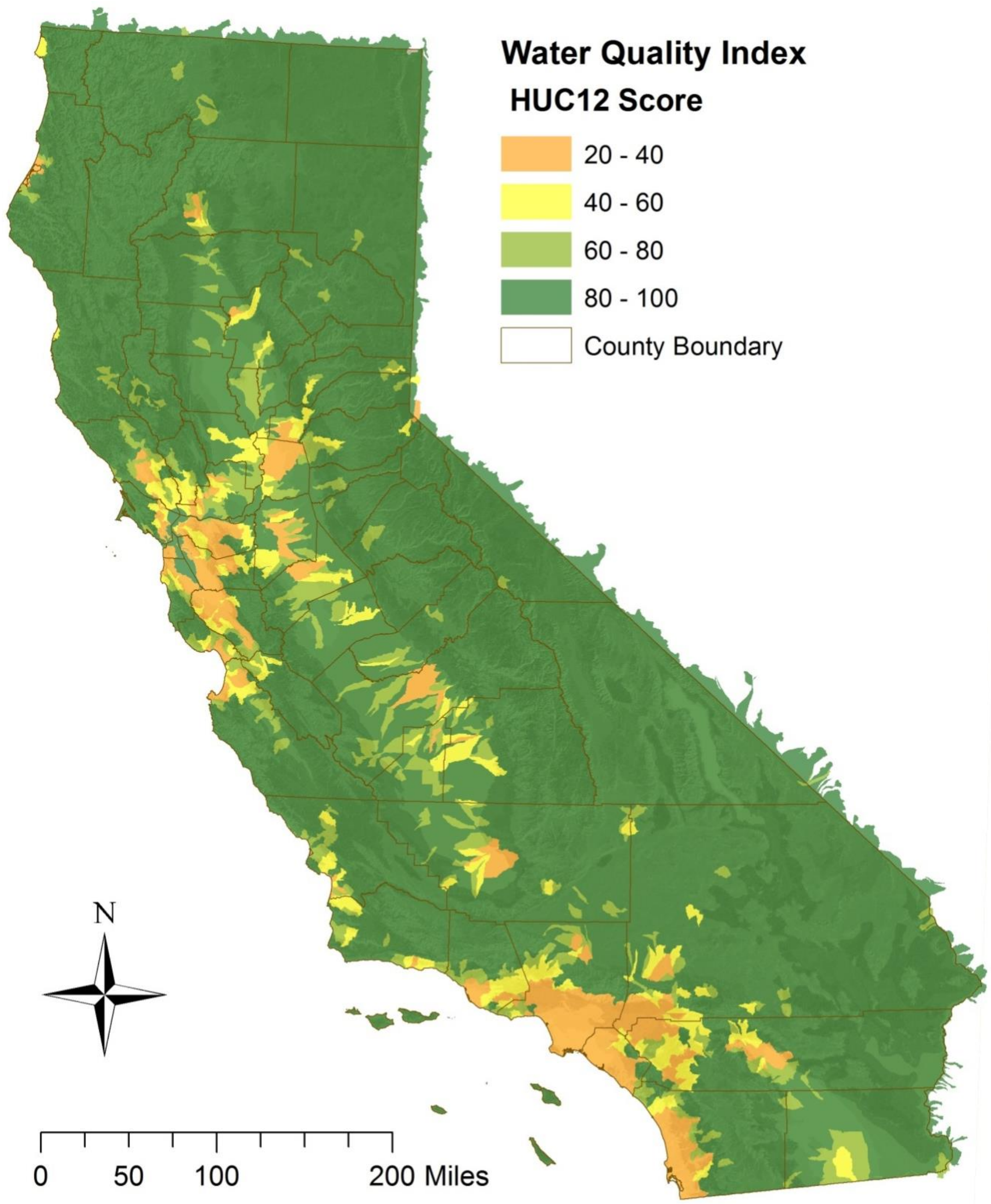


Figure 3. This map illustrates the Water Quality Index scores for each watershed with the hydrologic unit code classification of "HUC12".

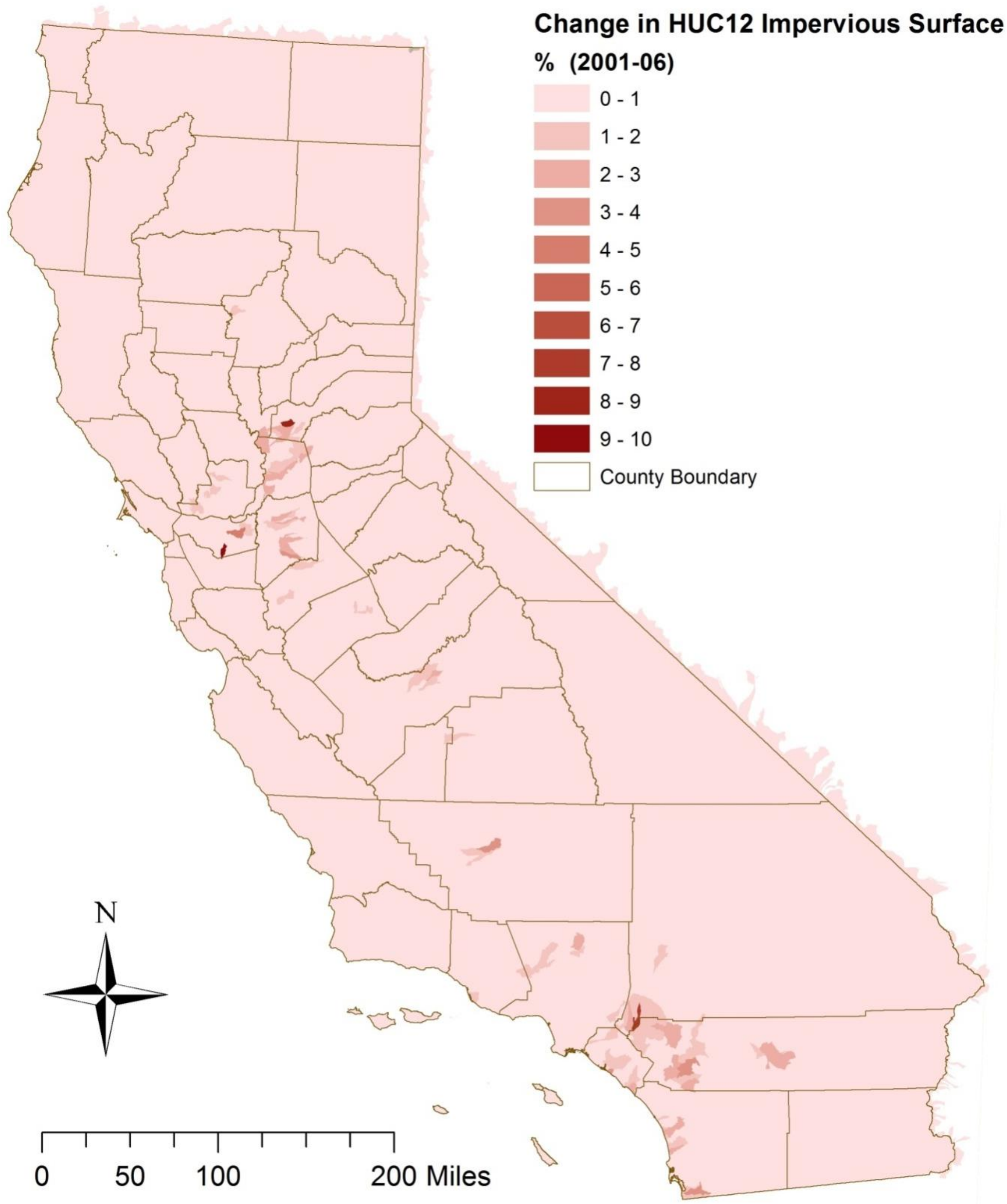


Figure 4. This map illustrates the change in mean percent impervious cover for each watershed with the hydrologic unit code classification of "HUC12" between the years 2001 and 2006.

Temporal and spatial resolution

Although percent impervious surface can be aggregated or displayed at the state level, it is more informative at smaller spatial scales that are appropriate to the analysis at hand. This is because the response of water quality, hydrology, and biotic condition to impervious surface will depend on the location and the scale of measurement. For example, when looking at fish richness, grouping physiographic regions or ecoregions based on species habitat requirements is more informative in developing predictive models than when examining the entire state of California with all its diverse aquatic habitats. Other considerations might include particular habitats, topographies, climates, and even degrees of development, both urban and agricultural.

Knowledge of local scales is also vital when percent impervious surface is simply used as an indicator to track speed and direction of development. For example, the rate of change in impervious surface between 2001 and 2006 was greater in the Sacramento are than in Los Angeles (Figure 5). But, the highly-developed Los Angeles region may, require more conservation action to protect or reverse negative impacts of impervious surface than the Sacramento region, while the Sacramento region still has some land not yet impacted by imperviousness, but could be managed to prevent many negative side effects. Therefore, it is important to remember that the state-wide analysis is best used as a starting point from which local analysis and policy decisions can be made.

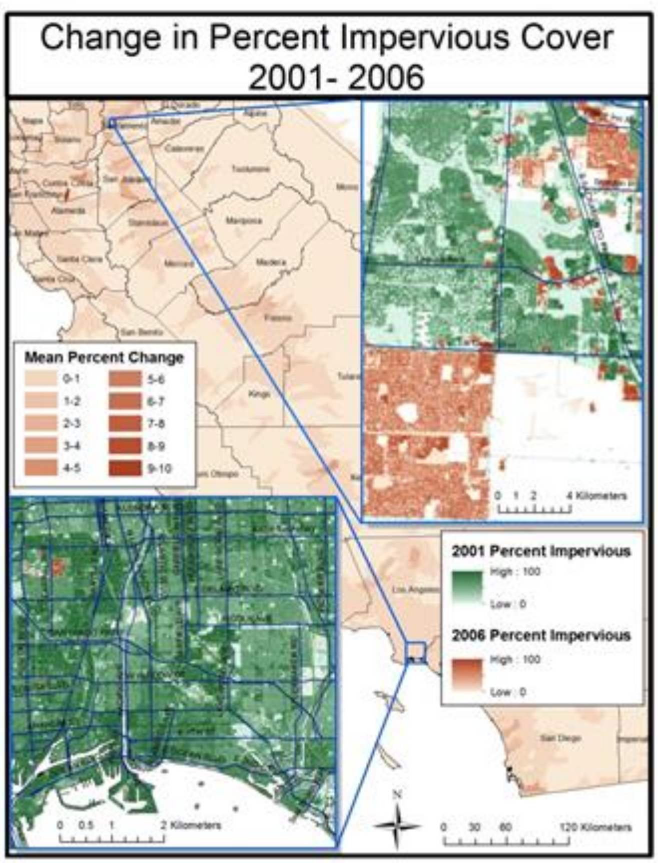


Figure 5. This map illustrates the both the change in mean percent impervious cover for each watershed with the hydrologic unit code classification of "HUC12" and the actual raster datasets for map extents covering the Sacramento and Los Angeles regions.

How sure are we about our findings (Things to keep in mind?)

The NLCD analysis is not perfect. Interpretations in land cover based on satellite imagery and subsequent applications of models to determine the percent impervious cover for the years 2001 and 2006 may not be wholly precise, but serve as a good estimate of impervious surface throughout the United States.

Our analysis relies on the zonal statistics function in ArcMap, which averages the raster values for percent impervious surface throughout the entire watershed. This removes the ability to detect finer-spatial changes in percent impervious surfaces (see Figure 5). Thus, calculations of geomorphic conditions from these statistics are not perfect, but represent a starting point from which more detailed analysis on finer spatial scales can begin. Ninety-five percent confidence intervals of the mean percent imperviousness were calculated for each sub-watershed, so some degree of understanding about our confidence in the mean values can be assessed (Figure 6). Confidence intervals are very small (<1%) for most watersheds.

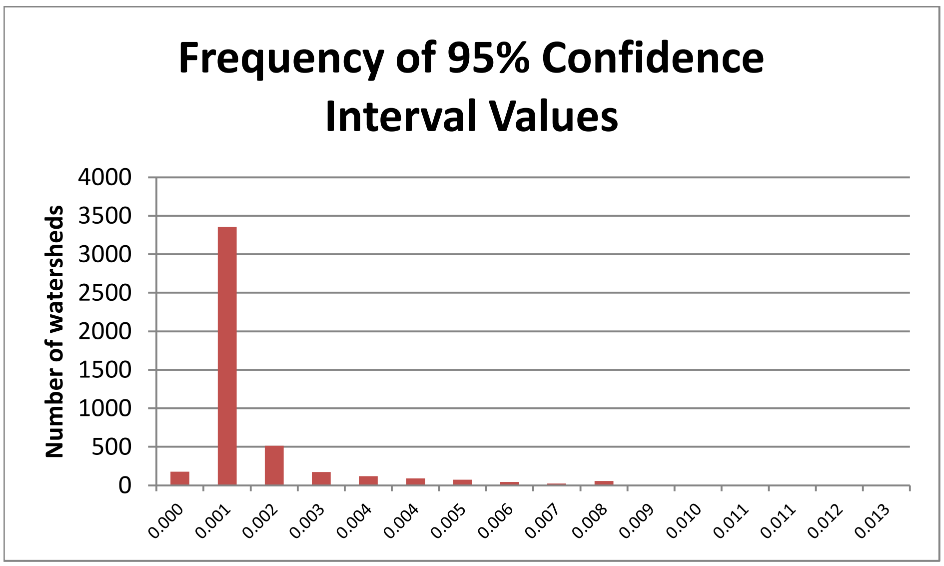


Figure 6. Frequency of 95% confidence intervals across HUC12 watersheds.

Technical Information

Data Sources

Spatial data for the impervious surface analysis come from:

2) United States Geological Survey
    a) National Land Cover Database
        i) Spatial data for years 2001 and 2006
        ii) Change in percent imperviousness

iii) Percent Imperviousness

Data Transformations and Analysis

Data were downloaded from the NLCD database in zip files that included raster files for import into ArcGIS. We used Arc GIS spatial software to display percent impervious surface throughout California. To illustrate effects on individual watersheds we used Hydrologic Unit Codes representing the smallest sub-watershed level (HUC 12). Zonal statistics within each sub-watershed resulted in means and standard deviation from which 95% confidence intervals were calculated. To illustrate change in percent impervious surface, zonal statistics were performed on spatial data for the change of impervious surface between the years 2001 and 2006. Because of challenges in comparing NLCD datasets from these two years, we used spatial data calculated by Fry et al. (2011) and Xian et al. (2011) for our analysis.

Water Quality Index

The water quality index (WQI) is a measure of water quality based on seven aspects of water chemistry: Total dissolved solids, suspended particle matter, fecal coliform, nitrate, phosphate, the chloride to sulfate ratio, and the nitrate to total nitrogen ratio. Schiff and Benoit (2007) use these seven parameters to calculate water quality using the following formula:

$$WQI = 10 - \left(\frac{10}{7}\right) \times \sum_{i=1}^{n} \left(\frac{P_i}{P_{i\,max}}\right)$$

Once WQI is calculated a line is fit to the data using an exponential decay transformation (Figure 7).

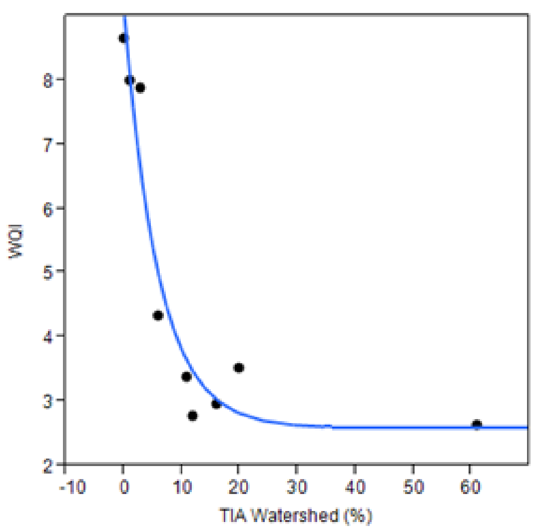


Figure 7. Water Quality Index (WQI) vs. Total Impervious Area (TIA) at the Watershed Scale. Adapted from (Schiff and Benoit 2007).

The resulting equation used for our model is:

$$a + b \times \exp(c \times TIA\ Watershed\ \%)$$

Where a=asymptote, b=scale, c=growth rate. For our analysis, the related values are 2.59, 6.50, and -0.17, respectively.

9. Water Supply & Use

Water used by residential and other use types compared to ground and surface supplies; 20% reduction by 2020.

Sustainability Goal:

Goal 2. Improve water supply reliability to meet human needs, reduce energy demand, and restore and maintain aquatic ecosystems and processes.

Sustainability Domain:

Water use/supply is tied to the indicator domain "water supply reliability", but can be indirectly related to ecosystem health and social benefits.

What is it?

This indicator covers a process category and serves as a potential contributing measure of impact on natural processes, economic activity, and social well-being. The amount of water used in residential, commercial, agricultural, industrial, and wastewater sectors is a very basic measure. To make it more useful in understanding sustainability, it could be tied to the supply of water in the environment. Supply could be based in ground-water systems, or surface water-bodies, or both. Although conservation and recycling could be thought of as an augmentation of supply, it may be more useful to consider conservation as reduced use and recycling as re-use.

To improve its utility in sustainability evaluation, water use/supply can be tied to productivity per unit-volume of water, water recycling, effects on ecosystems from which water is removed, and social and economic benefits realized by communities in using and conserving water.

- **Water Use:** The amount of water delivered and used is measured and estimated by various local, state, and federal agencies. Water provided from surface and ground sources through agencies and districts can be measured directly. Loss occurs when water leaks from the delivery systems. Actual water delivered may be different from the amount pumped, stored, and otherwise provided by an agency. Private wells are an important type of water provision, but the volumes of water from private wells can currently only be estimated in California.

- **Water Supply:** The total water volume in annual runoff and from ground-water sources constitutes the water budget for all human and non-human uses. The water supply part of the budget is defined here as the water available for human uses. Society values natural processes and sometimes protects them with statute. By definition, sustainability provides for enough water to maintain natural processes into the future. This can mean both: 1) sufficient flows in the summer to cover stream-bottoms and to keep water temperatures suitable for sensitive biota and 2) large enough flows in the winter and spring to do "geomorphic work" and connect channels to flood-plains. Geomorphic work refers to the maintenance of channels, banks, and floodplains through the movement and re-distribution of sediment, erosion of stream and river-banks, new channel formation, and island/bar formation.
- **Use/Supply:** Dividing the water used by the water supply, provides a useful indicator of how sustainable society's water use is instantaneously and from year-to-year and decade-to-decade. If water supply is defined as total natural water minus that required for natural processes, then to meet sustainability goals, the ratio of water use to supply will ideally be <1.

Basis of calculation and use

There are several important aspects of water use that can be considered: where the water comes from (source), the type of use it is put to (use), and the fate of the used water (recycled or wastewater). Every 5 years, the US Geological Survey estimates water use for every state at two sub-state scales, the county and the HUC-X watershed unit. Four sources and 8 categories of use are estimated at these scales, providing a comprehensive way to track water use. Accuracy is likely to be greatest at larger geographic extents (e.g., the state) and for the largest sources and uses. The most recent estimated water use for California was for 2005. These data were obtained and water sourcing and uses compared to available precipitation, population size, and economic activity.

Water supply is the water available to human use from the total water budget. Information about the water budget in California is challenging to obtain and requires an understanding and calculation of rates of precipitation, evapotranspiration (loss of water from plants), percolation into the ground, surface flows, surface impoundments, evaporative loss from impoundments, evaporative loss from the ground, and flow-rates of fresh-water to the ocean.

Why is it important?

The proportion of the water budget that society uses is one of the most fundamentals ways to measure our dependence on water and potential impacts on other systems dependent on the same water. Water sustainability is defined in the Water Plan as being related to our ability to provision ourselves with enough water to meet our needs, while also providing for the needs of future generations and natural systems. Measuring societal water use is akin to measuring how much oxygen we breathe. By itself, it just means we are functioning, when related to other measures, such as amount of total water and water supply, it tells us about our body's efficiency and ability to sustain itself.

Water use organized by geography, land-use type, economic activity, and demographics provides important information about economic efficiency and social equity. Comparing the rate of water use with current and projected rates of water availability can tell us whether increasing populations, water-demanding activities, and potential climate change impacts will affect the reliability of water supply.

What did we find out/How are we doing?

Water Supply

The supply of surface water in California varies considerably from year to year (Figure 1). The effect of inter-annual variation on piped water supply and water use is reduced through inter-annual water storage in reservoirs and use of groundwater.

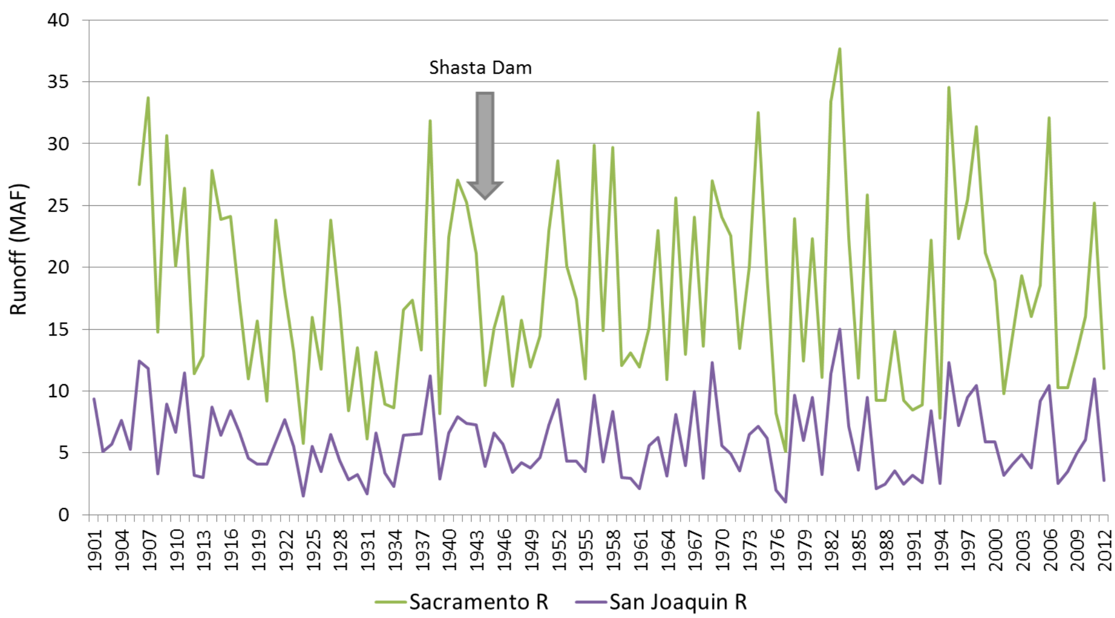


Figure 1. Runoff in the Sacramento and San Joaquin Rivers (1901 – 2012). Source: Department of Water Resources.

Water Use

Water use did not change very much in the years 1985 to 2005, based upon both USGS and DWR information sources. Because the state's population has been growing, this means that per capita consumption rates have been going down. In comparison, agricultural irrigation rates have not changed much overall, but the amount of irrigated land has decreased, meaning that the per-acre rate of irrigation has been increasing.

Although most managed water in California goes to agriculture, water use in urban areas is both an important type of use and an important area for conservation. Per capita residential water use has gone down over the last 20 years, but this may vary depending on the size of population centers. We found that counties with larger populations (>200,000) had lower per capita domestic/residential water use rates in 2005 than the average from the previous 10 years, than those with smaller populations (Figure 2). It may be that urbanized counties have greater reason to focus on water conservation and more resources to dedicate to this issue.

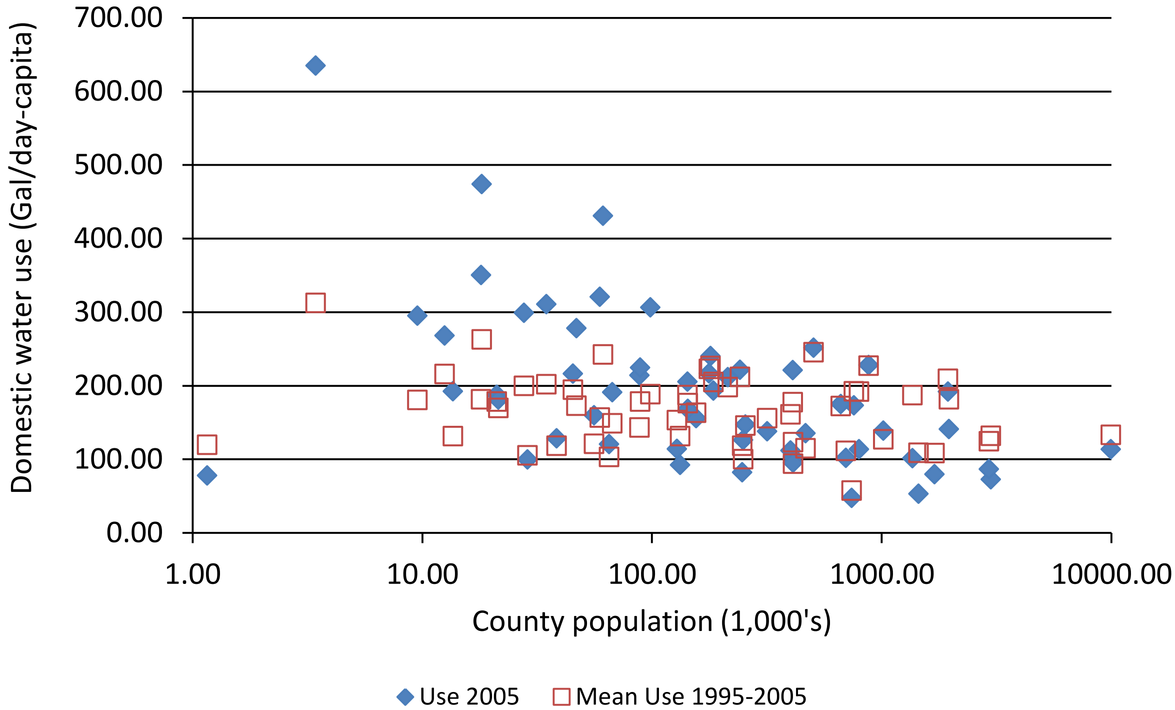


Figure 2. Domestic water use (gal/day-capita) compared to county population.

Most large California communities are on the coast, or in the Central Valley. The pattern shown in Figure 2 is reflected in the mapped distribution of urban water use by DWR Planning Area for the period 199-2005 (Figure 3). In this case, urban water use for certain areas (e.g., Los Angeles basin) are consistently <200 gal/capita-day, while other areas (e.g., Coachella Valley in DWR region 10) have water use rates in the thousands of gal/capita-day in some years. The primary statewide water conservation policy is the "20 by 2020" policy, which requires 20% reduction in urban water use by the year 2020, from a statewide baseline rate of 192 gal-capita/day (DWR, 2010). For DWR region 10, home of the highest rates of use, the interim target for 2015 is a use rate of 278 gal/capita-day and for 2020; the target is 211 gal/capita-day.

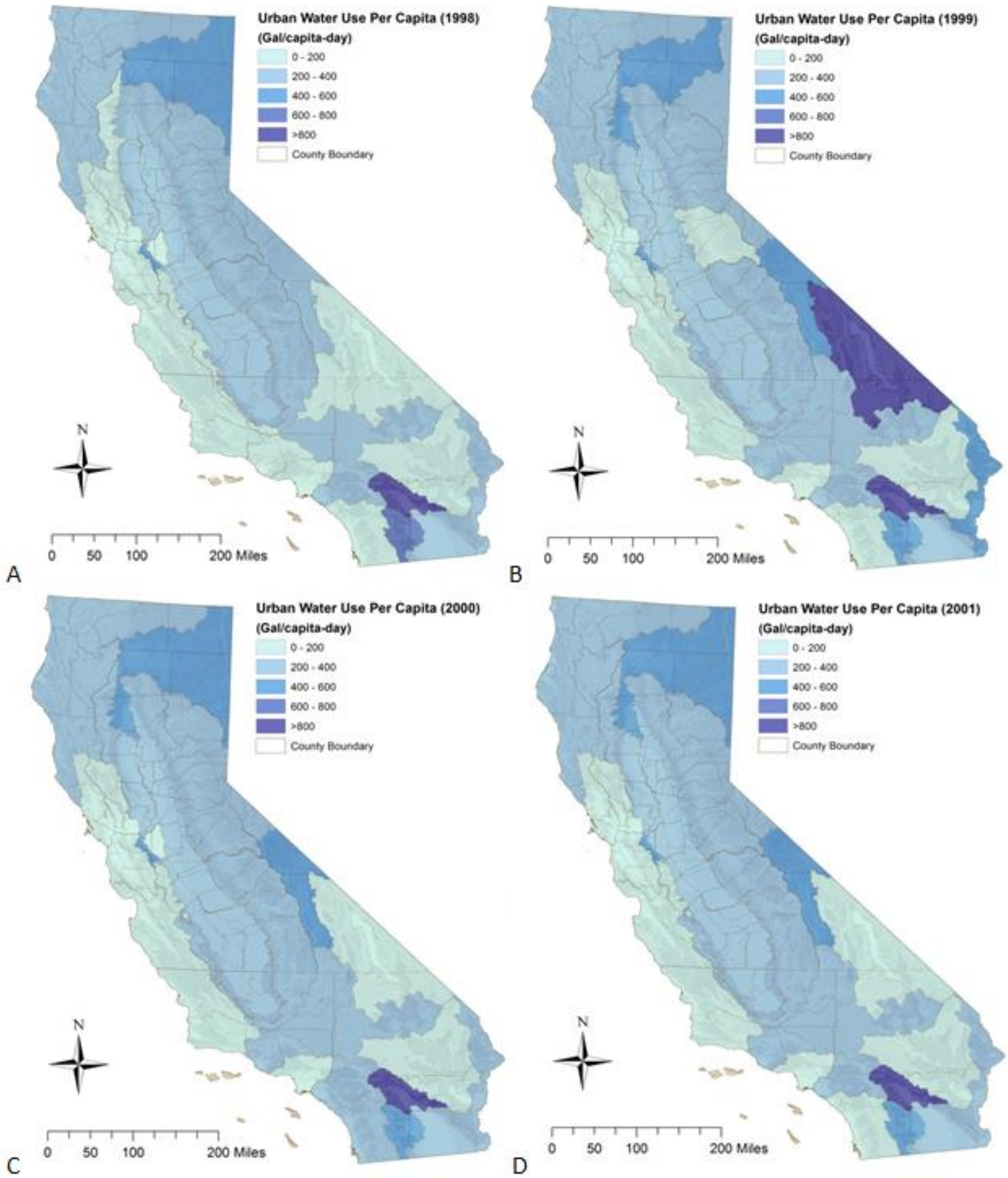


Figure 3. Distribution of urban water use by DWR Planning Area, expressed as average daily use for a given year, in gallons/capita-day. Source: California Department of Water Resources. A. 1998, B. 1999, C. 2000, D. 2001.

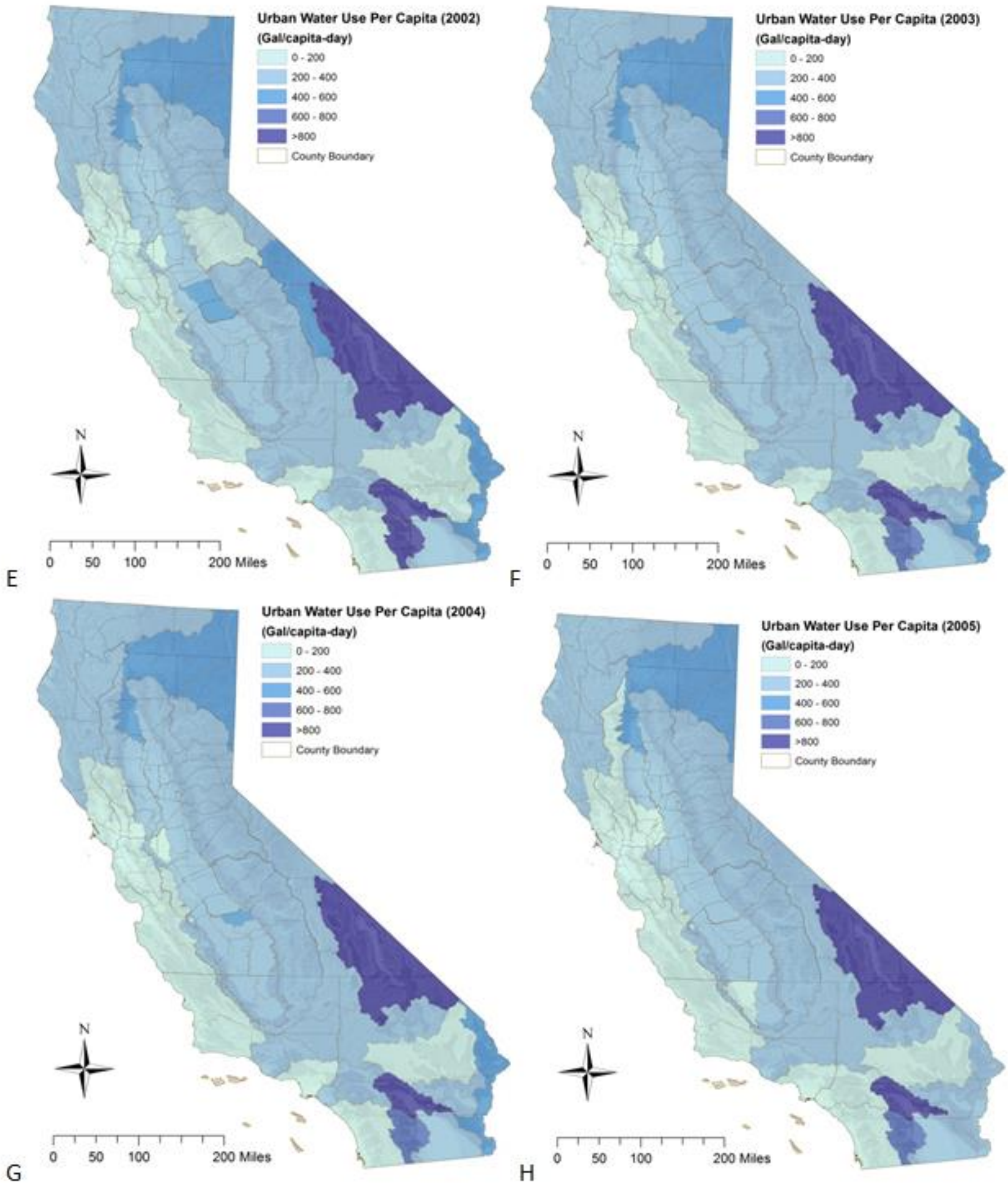


Figure 3 cont'd. Distribution of urban water use by DWR Planning Area, expressed as average daily use for a given year, in gallons/capita-day. Source: California Department of Water Resources. E. 2002, F. 2003, G. 2004, H. 2005.

Agricultural Productivity

Many agricultural areas in California rely on irrigation to promote crop growth. The amount of irrigation depends on the crop, climatic region of the state, and irrigation practices. One way to use information about water use for irrigation is to measure agricultural productivity, which can be indexed by measuring agricultural sales relative to the amount of water used (DWR, 2012).

There is remarkable variation in the agricultural sales relative to irrigation water use (Figures 4 & 5), which may be partially related to the coastal or inland position of the county (analysis not shown), and which may also be related to the type of crop grown (CDFA, 2012). For example, the counties with the lowest sales per unit and the highest water use rate are: Imperial, Sutter, Colusa. In these counties, farmers primarily grow cattle, lettuce, rice, walnuts, stone fruit, alfalfa, vegetables, tomatoes, and almonds. In the counties with the highest sales per unit water and highest water use rate, Monterey, Ventura, and San Diego grow berries, landscape plants, lettuce, celery, lemons, avocados, broccoli, and tomatoes. There is some overlap between the crop types for the least efficient and most efficient counties, which means that decisions about which crops to grow may not be made based on cost of water as a significant part of crop economics. This is reflected somewhat in the relationship between agricultural sales and applied irrigation water (Figure 5), which although generally positive, is highly variable and dependent on county.

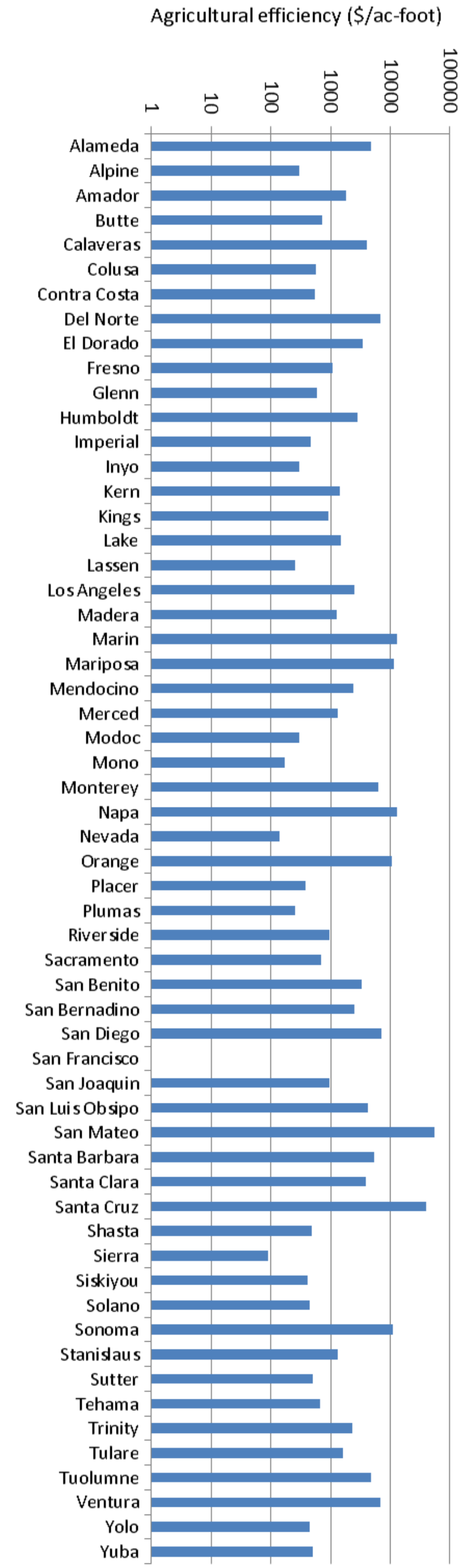


Figure 4. Agricultural productivity expressed as sales per ac-foot of water used for irrigation for each county in California.

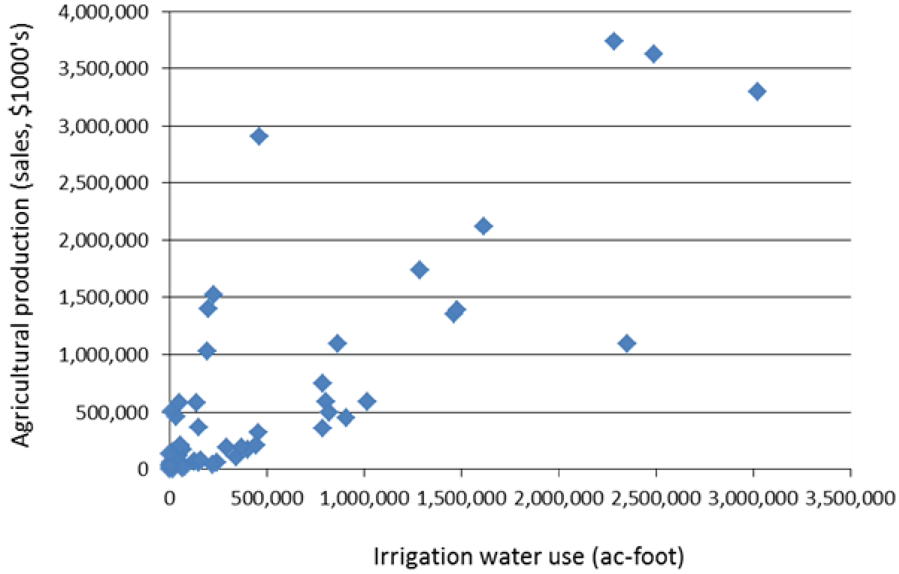


Figure 5. Agricultural productivity (sales in $) relative to irrigation water used (ac-feet). Each point represents an individual county.

Who else uses it?

- Millennium Ecosystem Assessment (http://www.millenniumassessment.org/en/index.aspx)
- State of the Environment, Western Australia 2007 (http://www.soe.wa.gov.au/report/overview.html)
- Indicators for environmental performance of watersheds in Alberta (http://environment.gov.ab.ca/info/posting.asp?assetid=7945&categoryid=5)
- State of the Fraser Basin Report: Sustainability Snapshot 3 (Canada, http://www.fraserbasin.bc.ca/publications/indicators.html)
- State of Our Environment City of Ann Arbor (http://www.a2gov.org/government/publicservices/systems_planning/Environment/soe07/Pages/ExecutiveSummary.aspx)
- The State of the Great Central Valley – The Environment (http://www.greatvalley.org/wp-content/uploads/2012/01/environmental-indicators-2011.pdf)
- Minnesota Watermarks – gauging the flow of progress 2000 – 2010 (http://www.gda.state.mn.us/pdf/2000/eqb/wtr_mrk.pdf)
- Minnesota Water Sustainability Framework – 2010 (http://wrc.umn.edu/watersustainabilityframework/index.htm)
- Sustainable Water Resources Roundtable
- Sustainable Industries Performance Indicator Framework (Ottawa)

What is the target or desired condition?

Conceptually, there are at least three target conditions: 1) that use not exceed water supply, especially from local or regional sources, 2) that water conservation and recycling are increasing to meet the 20% by 2020 standard for urban uses, and that 3) the most economic return possible is realized per unit of water use.

What can influence or stress condition?

One of the greatest determining factors of water use may be how much water we think we need/want, versus how much we actually need to survive or thrive. Residential water use corresponds roughly to water needed for personal, economic, and social activities. The basic human water need to maintain bodily function and for sanitation is 20-50 liters/day (~5-13 gal/day). To maintain food intake, an additional 2,000 to 5,000 liters per day (530-1320 gal/day) is needed to grow the food (UN-Water, 2012). Additional water is needed to maintain economic and social activity and at some point “water need” becomes “water desire” and water use may be greater than that actually needed (e.g., for irrigation of landscaped areas).

Water use for irrigation, cooling, and residential use may increase in response to atmospheric temperature. It may also increase when and where there is plenty of water available, if there is no perceived benefit from conserving or limiting water use. Water use has also decreased by public-relations and policy action in response to limits on total water availability in the environment (e.g., during drought-years in California).

Temporal and spatial resolution

Data are available at the scale of counties and HUC-8 basins. Other sources may have finer resolution data, for example, individual municipalities. The data presented here are useful at these county and basin scales and at the scale of the state, but not at finer resolutions.

Data are available for every 5 years (1985, 1990, 1995, 2000, and 2005), but not for recent years. These data are useful for understanding long-term, sectoral trends in water use, but not annual rates or trends in rate.

Technical Information

Data Sources

- USGS estimates of water use in the US
- CDFA Agricultural Statistics 2011-2012

Data Transformations and Analysis

None made

Aqueduct 2.0 Project Water Indicators

The Aqueduct 2.0 is a project of the World Resources Institute, which was the source of the indicators presented here (Gassert et al., 2013).

What is it?

The Aqueduct Water Risk Atlas makes use of a Water Risk Framework, that includes 12 global indicators grouped into three categories of risk (physical risk quality, physical risk quantity, and regulatory) and one overall score. The following Aqueduct project indicators were used in the Framework:

- **Baseline Water Stress**, which is the total annual water withdrawals (municipal, industrial, and agricultural) expressed as a percent of the total annual available flow;
- **Interannual Variability**, which is a measure of the variation in water supply between years;
- **Seasonal Variability**, which is a measure of the variation in water supply between months of the year;
- **Flood Occurrence**, which is the number of floods recorded from 1985 to 2011;
- **Drought Severity**, which is a measure of the average length of droughts times the dryness of the droughts from 1901 to 2008;
- **Upstream Storage**, which is a measure of the water storage capacity available upstream of a location relative to the total water supply at that location.
- **Groundwater Stress**, which is a measure of the ratio of groundwater withdrawal relative to its recharge rate over a given aquifer;
- **Return Flow Ratio**, which is the percent of available water previously used and discharged upstream as wastewater;
- **Upstream Protected Land**, which is the percentage of total water supply that originates from protected ecosystems;
- **Threatened Amphibians**, which is a measure of the percentage of freshwater amphibian species classified by IUCN as threatened.

Why is it Important?

Understanding how much water is available now, how much might be available in the future, how much of supply is consumed by society’s activities, and the impact of protecting and using water systems are all critical to managing human activities for water sustainability. Each of the indicators of the Aqueduct project is used in various parts of the world to inform water management. Collectively, they provide a powerful set of indicators of condition and risk to condition. Even if the assessment presented here is inaccurate for regions or watersheds of California, local or regional data can be used to evaluate the indicators in the future.

What is the target or desired condition?

The desired condition is for all indicators to be at “low risk”, because this is the condition most likely to result in sustainability over the long term. The undesired condition is for indicators to be at “very high risk”, which generally signals a large departure from a safe condition.

What can influence or stress condition?

The natural and human systems represented by the indicators will be influenced by different factors, depending on the indicator. In general, all are likely to be affected by climate change, which is likely to cause departures in temperature and precipitation from current conditions and ranges. Human population (numbers and settlement patterns), land use, and efficiency of water use are all likely to influence most of the indicators shown. The degree and direction (positive or negative) of effect will vary with indicator and influence.

What did we find out/How are we doing?

Each indicator from the Aqueduct 2.0 project was “clipped” to the extent of California. The indicators are presented using the raw values in Gassert et al. (2013), which are expressions of risk from “0” (low risk) to “5” (very high risk).

The geographic units scored are river basins and watersheds. Contiguous watersheds with similar risk scores may appear as one large region. Generally speaking, risk scores are ratios of a watershed or basin value and a base value, therefore risk scores for one indicator are not strictly-speaking comparable to scores for other indicators.

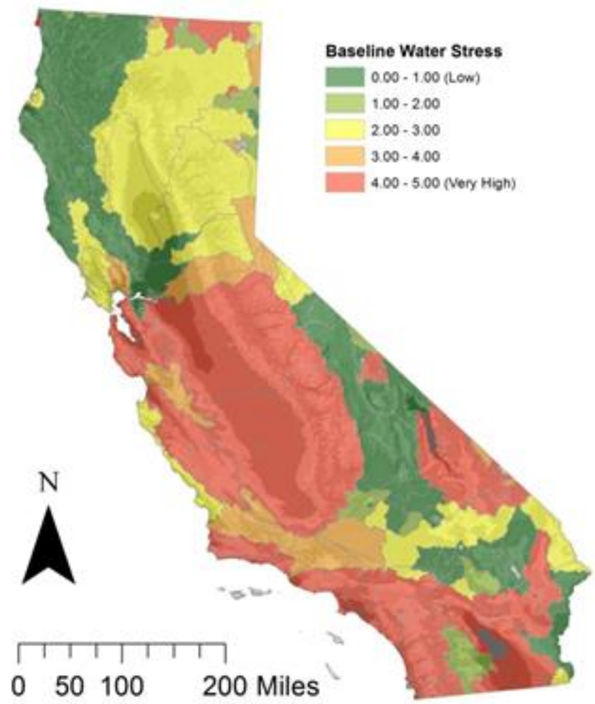


Figure 1. Baseline Water Stress, which is the total annual water withdrawals (municipal, industrial, and agricultural) expressed as a percent of the total annual available flow (withdrawals / available flow). Higher values indicate more competition among users. Arid areas with low water use are shown in gray, but scored as high stress when calculating aggregated scores.

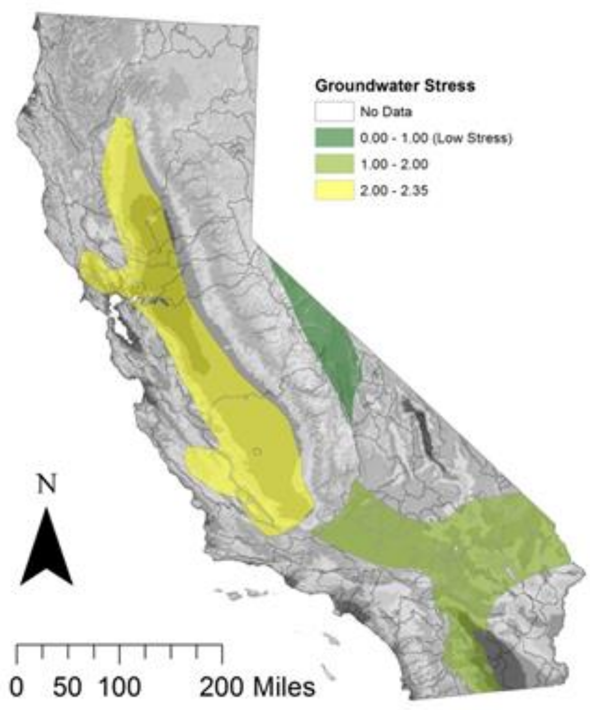


Figure 2. Groundwater Stress, which is a measure of the ratio of groundwater withdrawal relative to its recharge rate over a given aquifer (groundwater withdrawal / sustainable recharge). Values above one indicate where unsustainable groundwater consumption could affect groundwater availability and groundwater-dependent ecosystems.

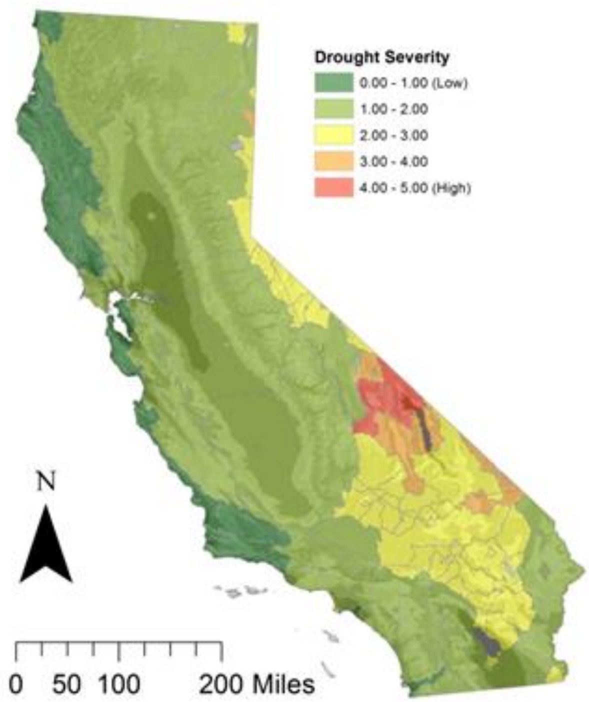


Figure 3. Historical Drought Severity, which is a measure of the average length of droughts times the dryness of the droughts from 1901 to 2008 (mean length x dryness).

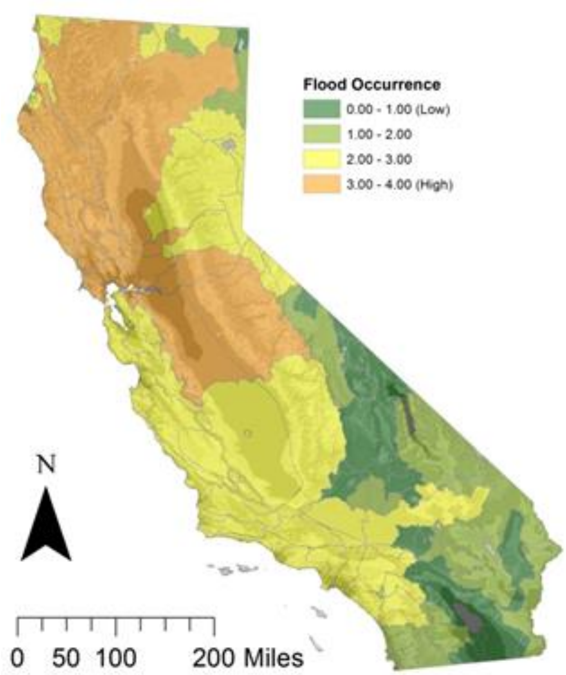


Figure 4. Historical Flooding, which is the number of floods recorded from 1985 to 2011.

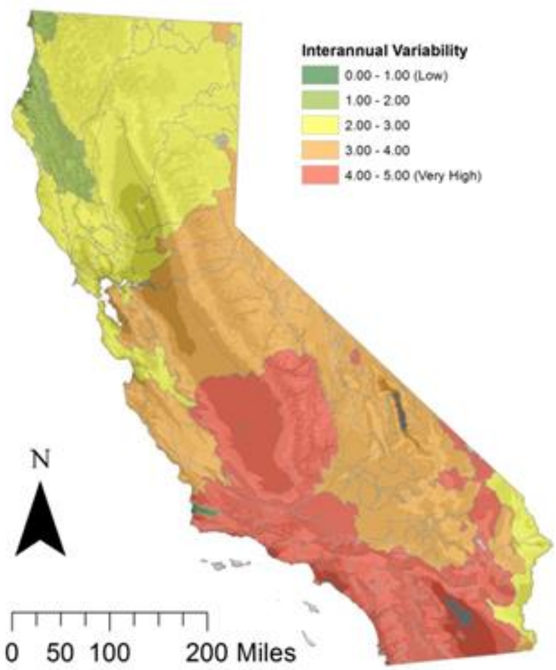


Figure 5. Interannual Variability, which is a measure of the variation in water supply between years (standard deviation / mean of total annual supply).

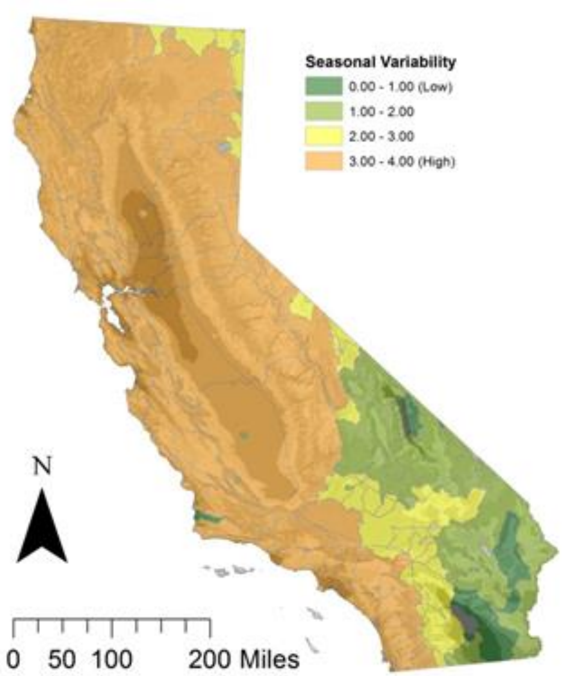


Figure 6. Seasonal Variability, which is a measure of the variation in water supply between months of the year (standard deviation / mean of total supply calculated using the monthly mean).

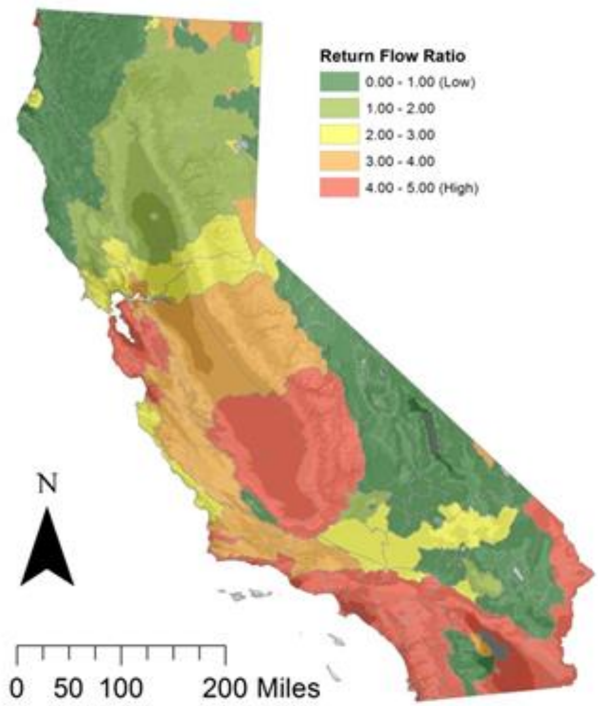


Figure 7. Return Flow Ratio, which is the percent of available water previously used and discharged upstream as wastewater (upstream non-consumptive use / available flow). Higher values indicate higher dependence on treatment plants and potentially lower water quality in areas that lack sufficient treatment infrastructure and regulations.. Arid areas with low water use are shown in gray, and scored as low stress when calculating aggregated scores.

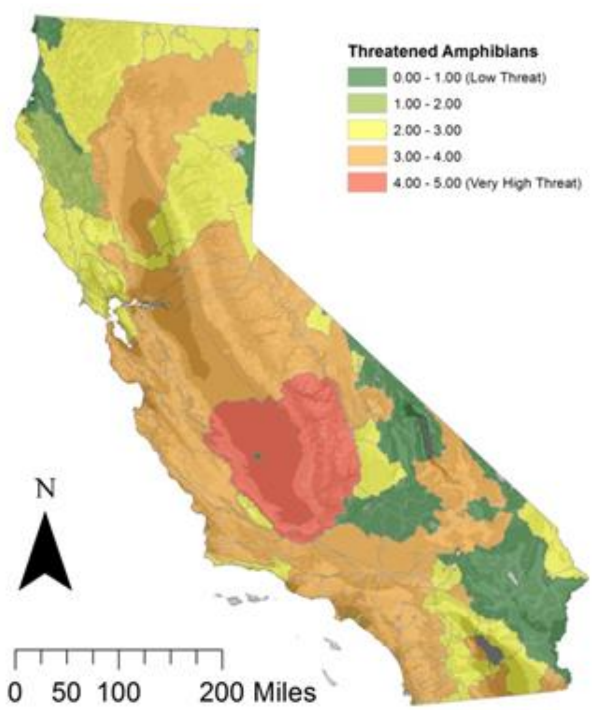


Figure 8. Threatened Amphibians, which is a measure of the percentage of freshwater amphibian species classified by IUCN as threatened (% freshwater amphibian species that are threatened). About ¾ of the state's watersheds are home to amphibian populations with moderate to very high threats, based on the proportion of amphibians that are legally threatened. Urban and agricultural areas, and mountainous regions downwind of these areas are most under threat.

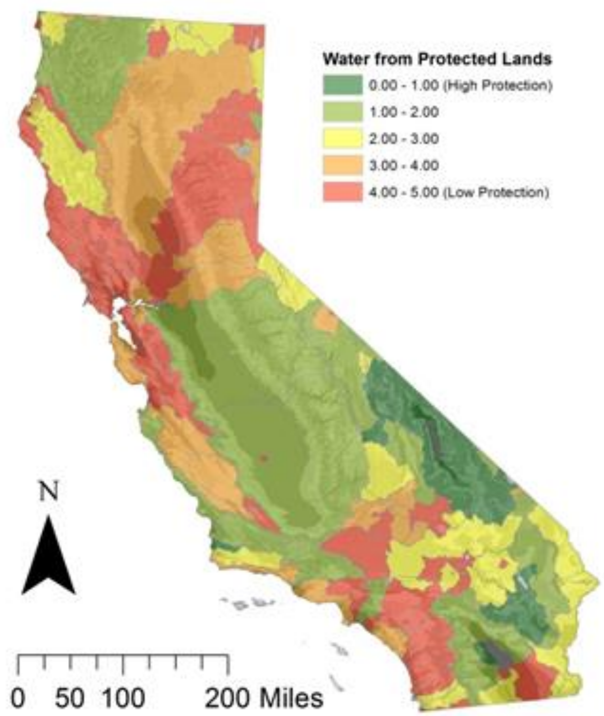
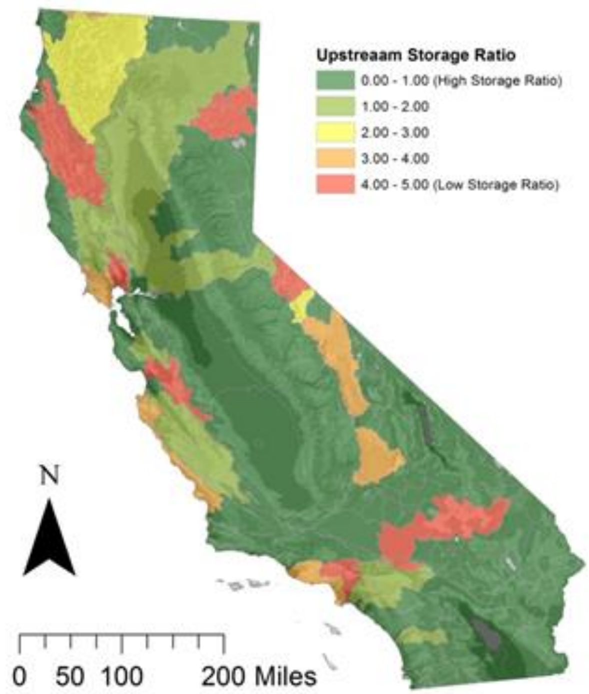


Figure 9. Upstream Protected Land, which is the percentage of total water supply that originates from protected ecosystems (% total supply originated in protected lands). Modified land use can affect the health of freshwater ecosystems and have severe downstream impacts on both water quality and quantity.

F

Figure 10. Upstream Storage Ratio, which is a measure of the water storage capacity available upstream of a location relative to the total water supply at that location (total supply / upstream storage capacity). Higher values indicate areas more capable of buffering variations in water supply (i.e. droughts and floods) because they have more water storage capacity upstream.



Temporal and spatial resolution

The data for individual indicators are available over different time frames, varying from long timeframes with recent data (flood occurrence), to single data points that are already a few years old (e.g., pre-2004 consumptive use, which is part of several indicators). Ideally, the indicators would be evaluated annually, for measures with rate processes, or at longer periods where conditions will not change quickly (e.g., upstream protected land).

The base data for the indicator vary considerably, but in general were collapsed to the watershed-basin scale. This scale of expression may hide the actual resolution of the data, which may affect confidence and use of the data.

Technical Information

Data Sources

The risk scores were downloaded as a spatial dataset from the Aqueduct 2.0 project website: http://www.wri.org/publication/aqueduct-global-maps-20; the data sources are described in the metadata on the website.

Data Transformations and Analysis

The spatial dataset initially downloaded was the global dataset. These data were clipped in ArcGIS 10.x to the border of California. No modification of the risk scores was conducted. The risk scores were calculated and put in risk categories using the formulae and categories in Table 1 below.

Table 1. Categories and Formulas

Name	Score Calculation Formula	0-1	1-2	2-3	3-4	4-5
Baseline Water Stress	(LN([raw_value])-LN([c1]))/LN([base])+1	Low (<10%)	Low to medium (10-20%)	Medium to high (20-40%)	High (40-80%)	Extremely high (>80%)
Inter-annual Variability	([raw_value]-[c1])/[base]+1	Low (<0.25)	Low to medium (0.25-0.5)	Medium to high (0.5-0.75)	High (0.75-1.0)	Extremely high (>1.0)
Seasonal Variability	([raw_value]-[c1])/[base]+1	Low (<0.33)	Low to medium (0.33-0.66)	Medium to high (0.66-1.0)	High (1.0-1.33)	Extremely high (>1.33)
Flood Occurrence	(LN([raw_value])-LN([c1]))/LN([base])+1	Low (0-1)	Low to medium (2-3)	Medium to high (4-9)	High (10-27)	Extremely high (>27)
Drought Severity	([raw_value]-[c1])/[base]+1	Low (<20)	Low to medium (20-30)	Medium to high (30-40)	High (40-50)	Extremely high (>50)
Upstream Storage	-(LN([raw_value])-LN([c1]))/LN([base])+1	High (>1)	High to medium (1-0.5)	Medium to low (0.5-0.25)	Low (0.25-0.12)	Extremely low (<0.12)
Ground-water Stress	(LN(IF([raw_value]<5, MIN(5,[raw_value]+1.5), [raw_value]))-LN([c1]))/LN([base])+1	Low (<1)	Low to medium (1-5)	Medium to high (5-10)	High (10-20)	Extremely high (>20)
Return Flow Ratio	(LN([raw_value])-LN([c1]))/LN([base])+1	Low (<10%)	Low to medium (10-20%)	Medium to high (20-40%)	High (40-80%)	Extremely high (>80%)
Upstream Protected Land	-(LN([raw_value])-LN([c1]))/LN([base])+1	High (>40%)	High to medium (20-40%)	Medium to low (20-10%)	Low (10-5%)	Extremely low (<5%)
Threatened Amphibians	(LN([raw_value]+0.05)-LN([c1]))/LN([base])+1	Low (0%)	Low to medium (1-5%)	Medium to high (5-15%)	High (15-35%)	Extremely high (35-100%)

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Appendix B. Region-Scale Test of the California Water Sustainability Indicators Framework

The following pages provide the results of the pilot test of the Framework at the region scale. The pilot test was carried out with the Council for Watershed Health (CWH) and the Santa Ana Watershed Project Authority (SAWPA), so the style of reporting is slightly different from the state-scale pilot test. The first part of the pilot test description is a summary of the process, goals, and findings, The second part of the description consists of indicator specific information and findings. The indicators that were evaluated are shown in Table 1 below. For each indicator, there is a description of the indicator, why it is important, the findings for the SAWPA area and brief description of how the indicator was scored.

Table 1. Evaluated Indicators

Indicator Name
Proportion of Water Use from Imported and Recycled Sources
Water Use (per capita)
Local Water Supply Reserves
Adoption of Sustainable Water Rates
Water Availability and Stress (WRI Aqueduct 2.0)
Annual Water Resource Energy Use Relative to Rolling Average
Stream Network with Natural Substrate Benthos
Impervious Surface: Water Quality Index and Geomorphic Condition
Coastal Impacts from Sea Level Rise
Aquatic Habitat Fragmentation
Open Space for Recreation
Invasive Species and Native Landscapes
Area with Restoration Projects and Conservation Agreements
Exceedance of Water Quality Objectives in Watershed
Exceedance of Groundwater Salinity Standards
Exceedance of Water Quality Objectives at Discharge
Exceedance of Water Quality Objectives at Recreation Sites
Biological Condition Index
OWOW (Stakeholder-Community) Participation

Region-Scale Test of the California Water Sustainability Indicators Framework: Indicators of Health for the Santa Ana River Watershed

August 20, 2013

A Report of the Council for Watershed Health; University of California, Davis; and the Santa Ana Watershed Project Authority

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1.0 Introduction

Human well-being is inextricably tied to the services provided by healthy ecosystems and yet vulnerable to the increased threats posed by major crises or events, which SAWPA has labeled the *Four Horsemen of the Apocalypse.* The crises threaten the future of a sustainable Santa Ana Watershed. The *Four Horseman*[2], or major threats, are:

- Climate Change
- Colorado River Continuing Drought
- Sacramento-San Joaquin Delta Vulnerability
- Population Growth and Development

Climate and ecosystem stressors reduce the reliability of the water supply system, the rivers and beaches are polluted by urban runoff, development of new communities interrupts hydrology and groundwater recharge, wetlands and riparian habitat have been lost with urbanization and the conversion of rivers to reduce flood risks, wildlife habitat continues to decline with development, frequent wildfires threaten to convert native ecosystems to non-native grasses, and people in urban communities have too few parks and little access to wild open spaces.

It is vital that we value and communicate these connections between natural systems and humans in order to cause change. Understanding and communicating about environmental and community conditions over the long-term is a critical aspect of sustainable environmental management and policy formulation. Working with the landscape and its natural processes, using sound science, listening to stakeholders, and integrating actions across multiple priorities yields multiple benefits cost effectively. The approach can only be implemented when agencies and organizations work together towards a shared vision. Developing an integrated assessment for reporting on the state of our environment is the most effective way to describe and encourage the progress towards this vision.

This report describes the methodology of an integrated assessment of the Santa Ana watershed and also provides the findings of a current assessment. The assessment we describe augments the Santa Ana Watershed Project Authority (SAWPA) One Water One Watershed (OWOW) goals and objectives, strategies, and targets. The resulting assessment reports on status and trends of the economic, ecologic and social systems that make up the watershed.

This scientific, data-driven watershed assessment benefits local, regional, state and federal agencies and organizations by conveying a systematic, scientific evaluation of conditions developed for and presented to a wide-ranging audience. Integrated assessment and reporting of environmental and community conditions may promote cooperative management and decision-making by increasing the public's awareness of regional conditions. In addition, this report describes a mechanism for future monitoring and tracking and is designed to meet the IRWM

[2]http://www.sawpa.org/owow/about-owow/

requirements for Plan Performance and Monitoring while also providing OWOW with a mechanism for celebrating successes, drawing resources to challenges, and improving the health of the Santa Ana watershed.

Regional targeted assessments have been deployed elsewhere in the United States and internationally. The report card produced by the Chesapeake Bay Foundation is perhaps the most visible in the US and provides a public accounting for communities and municipalities within the Chesapeake Bay watershed, stimulating restoration of critical habitats.

Similar to the Chesapeake Bay, the communities in the Santa Ana River watershed are critical to the economy of California and the nation. The health of the economy and the environment are inextricably linked. Routine, collaborative and structured assessments of conditions of the economy, society, and ecology provide an important feedback into the integrated regional water management.

We know that what we measure affects what we do in powerful ways.

2.0 Framework for the Assessment

As a component of the OWOW 2.0 plan, this watershed health assessment provides metrics for understanding the performance of integrated water management in the watershed. Using this assessment tool, SAWPA and the OWOW Pillars can produce an effective, efficient and responsive ongoing monitoring program for the watershed. OWOW Pillars are groups of interested stakeholders focused on one topic, such as water supply. The current Integrated Regional Water Management guidelines from Department of Water Resources (DWR) require inclusion of performance monitoring in all Integrated Regional Water Management (IRWM) planning efforts.

2.1 Project Process and Methodology

The development and analysis of a framework for indicator assessment was a collaborative process among SAWPA, the Pillars, Council for Watershed Health, and Dr. Fraser Shilling, UC Davis. The methodology was developed using a framework first used to implement the California Watershed Assessment Framework (WAF), which is itself a derivative of a U.S. Environmental Protection Agency Science Advisory Board framework (EPA 2002). The techniques and technology of the Framework are well accepted by the California Department of Water Resources (DWR) and are being used in the development of the Sustainability Indicators Framework, under the California Water Plan 2013 Update. The current guidelines from DWR require inclusion of performance monitoring in all Integrated Regional Water Management (IRWM) planning efforts.

A system of ecosystem assessment encourages measuring indicators of these essential watershed attributes such as water temperature, fish populations and concentrations of certain chemicals that contribute to an evaluation of, for example, biotic conditions. Indicators convey the condition of components of the system relative to goals for the system. Over time the report card maintains consistency in the measured indicators, the targets for each indicator, and goals for the system.

The Framework has two key strengths. First, it uses existing watershed management goals as the focus of the assessment. This allows a variety of managers to participate in creation of the assessment, and assures actionable results for implementation. The watershed management goals drive selection of indicators and metrics that can often be drawn from existing datasets or data collection efforts.

Second, the Framework uses “distance to target” as the method for describing the condition or state of each indicator. The process identifies a range from best case to worst case for the indicators, which are then described as existing somewhere in that range. This permits indicators that are significantly different to be compared to one another by describing where we are compared to where we want to be. For instance, a measure of per capita water use can be compared to the presence of in-stream benthic invertebrate species because both will be scored based on their current condition compared to their target condition.

The process included presentations of the Framework and its application in working sessions orchestrated by SAWPA for the appropriate stakeholders. This learning process included both small-group meetings with SAWPA staff as well as larger-scale stakeholder sessions with the Pillars.

2.1.1 Goal & Objective Development

Using a facilitated, stakeholder process, we analyzed the goals and objectives in the original OWOW plan and compared them to the OWOW 2.0 Framework to identify and fill gaps. We then used performance targets highlighted in OWOW as the starting point to develop an appropriate suite of indicators and metrics for the Santa Ana watershed that addresses the needs of the community, the ecology, and the IRWM planning requirements. Finally, we populated the indicators set with distance-to-target scores derived from research, data collection and data analysis. This step relied heavily on existing datasets and data collection managed by SAWPA.

2.1.2 Indicator Selection and Analysis

Thoughtful selection of indicators should be derived from the starting framework of goals and objectives. Most indicators, however, are chosen because information is available or is likely to become available to inform evaluation. Quantitative indicators are typically parameters that are familiar from monitoring programs (e.g., # spawning salmon) that become indicators when they are chosen to represent important parts of social-ecological systems.

Because of the special role that indicators play in public education and decision-making, data sources should be carefully tracked and their provenance recorded through the indicator framework process. Data provenance refers to the described pathway that data for each selected indicator takes to become meaning as part of indicator evaluation. This pathway begins with justification for why a particular dataset is chosen to data management in a retrievable form linked to reporting on indicator condition.

This provenance pathway continues seamlessly with data analysis and reporting, which can be organized using the scientific workflow technique. Scientific workflows offer both a theoretical as well as a practical way for building a comprehensive environment for data management, analysis, and decision support. Scientific workflows combine scientific data and process workflows, and provide a graphical interface to manage the pipeline of steps of a scientific problem (Ludäscher et al 2009). One can think of scientific workflows as similar to a flowchart, where the various nodes represent computational tasks and the lines connecting each step are the informational inputs and outputs for each step. Each step can either be automated, such as an analytical task, or semi-automated, where external input and responses are required to complete the steps.

2.1.3 Distance to Target

Comparing indicator-parameter values to a reference or target condition is a critical step in the Framework. This is where sustainability meaning is attached to the data. There are a variety of ways to measure and normalize measurement of parameter conditions to target or reference conditions.

In the Framework, normalization is carried out where each indicator is evaluated compared to a pair of reference or standard values (axiological normalization). Typically, there is a reference for "unwanted condition" (score = 0) and "wanted condition" (score = 100). When this is done for each indicator and each time point, the result is a "distance to target" value that can be on a 0-100 (or similar) scale. An important benefit of comparing indicator condition to targets is that scores can be combined across very different indicators (e.g., water temperature and fish tissue mercury concentrations), whereas otherwise this would not be possible. Because all indicator conditions

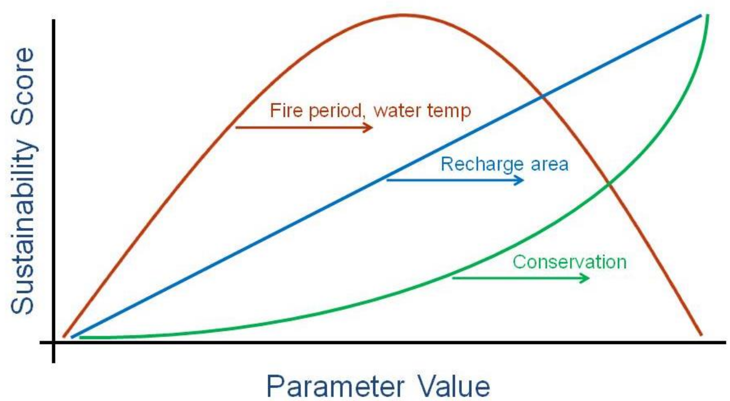

Figure 1. Non-linear relationships between parameters and equivalent sustainability scores

are quantitatively compared to a target, they will all be normalized to the same scale — distance to target. Once the normalization takes place, the new values, ranging from 0 to 100, mean the same thing and can therefore be compared, or aggregated. Because environmental and socio-economic processes and conditions rarely respond to influences in a linear fashion, evaluating indicators relative to reference conditions must also take into account these non-linear responses. For example, evaluation of water temperature should follow a non-linear function because biological processes may respond non-linearly to changes in temperature (Figure 1). Other processes or attributes may have a linear relationship, or power relationship to sustainability score (Figure 1).

2.1.4 Variance and Confidence

The degree of certainty in the indicator evaluation results depends on two conceptual questions: whether good indicators were chosen and how well the data presented for each indicator accurately reflect the real status or trend in the metrics. The first of these questions pertains to the indicators themselves and how well they address the objectives or attributes they are meant to represent. Certainty about the indicators depends on four main factors: importance, understanding, rigor, and feasibility.

The second question pertains to statistical confidence in the data presented for each indicator. The available data may contain a variety of sources of uncertainty including: measurement error, uncertain or inappropriate use of the sampling frame, sampling error, and process error. Any of the above sources of uncertainty affects confidence in the estimates of status and reduces the ability to detect trends over time. For some indicators quantification of different sources of uncertainty in the data may be possible, but in many cases there are limitations to providing a qualitative description of the likely sources of error and associated magnitude. Reporting confidence, certainty, and/or variance is important to building trust for the indicators framework.

2.2 Goals

Using the process described in section 2.1.1 above, the Pillars selected five areas for which to develop goals for OWOW 2.0: water supply, hydrology, open spaces, beneficial uses, and effective & efficient management. The goals and objectives for each of these five areas are detailed in this section.

2.2.1 Water Supply

Goal: Maintain reliable and resilient water supplies and reduce dependency on imported water

Objectives: increase use of rainfall as a resource, increase use of recycled water, decrease water demand, increase water-use efficiency, sustainably develop local water resources, maintain sufficient storage to overcome multi-year (3 year) drought over a ten year hydrologic cycle, reduce green-house-gas emissions and energy consumption from water resource management.

The Santa Ana River Watershed, among all the services it provides, is the source of a great deal of the water used by human communities, and virtually all of the non-human communities. The supply of good quality water to communities and the environment is foremost in the management effort of the watershed, and this goal seeks to understand the effectiveness and efficiency of the water supply system.

2.2.2 Hydrology

Goal: Manage at the watershed scale for preservation and enhancement of the natural hydrology to benefit human and natural communities

Objectives: Preserve and restore hydrologic function of land, preserve and restore hydrogeomorphic function of streams and water bodies, safely co-manage flood protection and water conservation, include ecosystem function in new development planning and construction

The physical processes of the watershed exist on the land and in the water. This goal highlights how managers of water and land (and the relationship between the two) are striving to protect and restore natural processes that benefit other goals within the watershed, like supply or habitat augmentation.

2.2.3 Open Spaces

Goal: Preserve and enhance the ecosystem services provided by open space and habitat within the watershed

Objectives: Increase the capacity of open space to provide recreational opportunities without degrading its quality or increasing its consumption of water & energy; protect existing and restore native habitats; manage aquatic and riparian invasive species; protect estuarine and marine near-shore habitats; reduce ornamental irrigated landscapes; improve management support for landscaping that utilizes native vegetation ; protect endangered and threatened species and species of special concern through improved habitat

Like the Hydrology goal, the desire to protect open spaces reveals efforts to maintain land in a natural condition. Here, however, the focus is more on the habitat and recreational value of the open space. Changing the ethic for managing developed open space, even at the household scale, is also included here, found in the objectives to diminish irrigation and water-intensive ornamental landscapes.

2.2.4 Beneficial Uses

Goal: Protect beneficial uses to ensure high quality water for human and natural communities

Objectives: Attain water quality standards in fresh and marine environments to meet designated beneficial uses; protect and improve source water quality; achieve and maintain salt balance in the watershed

Strong Federal and State regulatory authority drives water quality management. This goal acknowledges the need for water quality on the surface and in the ground to be improved through management changes.

2.2.5 Effective & Efficient Management

Goal: Accomplish effective, equitable and collaborative integrated watershed management in a cost-effective manner

Objectives: Improve regional integration and coordination; ensure high quality water for all users; balance quality of life and social, environmental and economic impacts when implementing projects; maintain quality of life; provide economically effective solutions; engage with disadvantaged communities to leverage capacity to effectively respond to their needs; engage with Native American tribes to leverage capacity to effectively respond to their needs; reduce conflict between water resources and protection of endangered species

This goal is at the heart of the OWOW process, saying that only through inclusive collaborative processes can the necessary unity of purpose be achieved. Managing the Santa Ana watershed requires actors at multiple scales and with vastly different authorities and responsibilities. Through an adaptive management process OWOW seeks to achieve the correct organization of decision-makers for the decisions that must be made. Despite this goal being central to the process of OWOW, it was extremely difficult to resolve indicators of its distance to target, as can be read below.

3.0 Findings

As is the case for all watersheds in coastal California, there is degraded water and habitat quality in much of the lower Santa Ana watershed and parts of the upper watershed. High levels of land protection in the upper watershed provide some balance to the lower watershed conditions. Water supply reliability benefits from water use efficiency by users and municipalities and is challenged by persistent groundwater quality issues, unpredictable effects of climate change, and low (but improving) rates of water recycling. The SAWPA service area has benefited from the open OWOW process and active attempts to recruit community members to meetings. At the same time, the rate of community involvement is very low relative to the very large population impacted by the conditions of the watershed and the decisions of those managing it.

Below is a synopsis of the indicators selected for each goal, and what the analysis told us about the Watershed. Throughout the findings below are found “Incomplete” scores for a number of indicators. This reflects a decision to include indicators that can provide an understanding of the distance to the target goal; however, those indicators either do not have a robust data set or are lacking a rigorous technique for assessing the indicator.

3.1 Water Supply

Maintain reliable and resilient water supplies and reduce dependency on imported water

The water supply for the communities of the Santa Ana watershed has long been sufficient to the need. However, it has also been reliant on a known climate, the availability of affordable imported water, and an economy and population with small but consistent growth. In this goal, the OWOW 2.0 plan acknowledges that to maintain reliability of water supply the system needs to become more resilient to change, primarily by reducing the most variable and threatened component of the supply: imported water.

Five indicators were analyzed about this goal. They allow an understanding of how effectively the watershed is using local water supplies as compared to imported, and how the community of the watershed is conserving both individually and through policy. Also an indicator of on-hand stored water was studied to describe the region's ability to withstand being cut off from imported supplies. The table below shows these five indicators and how they were scored.

The Santa Ana Watershed does well to use local and recycled water supplies. This is true primarily due to the use of local groundwater and the increasing use of recycled water. Using reported data from water retailers, which includes service to 8.9 million residents; residential per capita water use throughout the watershed is 114 gallons per day per person (gpd), which is below the baseline of 126 but still above the 2020 goal of 104. However, about 1/3 of the residents of the watershed are still using more water per day than the baseline. To achieve the 2020 goal, the watershed needs to reduce total residential usage by about 9%. To-date, slightly more than half of the water retailers have adopted sustainable water rates.

The watershed is well positioned to withstand a three-year local drought, as was calculated by reviewing the expected demands and supplies during dry conditions. When two three-year local droughts back-to-back were considered, groundwater supplies became strained, and imported water demand climbed. In future assessments, this indicator should consider both droughts and the potential challenge of a multi-year imported water interruption from infrastructure failure.

The indicator of energy use in the water resource sector shows a continued increase of energy use and carbon emissions. The low indicator score reflects the 3.4% increase in 2012 over the five-year average.

The World Resources Institute has identified a multi-metric analysis for judging water availability and stress. As a globally applied indicator, it describes the balance of water use to water availability, and describes water supply reliability and source-water protection. This analysis is being used by Department of Water Resources as component of the Water Plan Update 2013, and was downscaled and included within the technical appendix for reference, but was not associated with the scoring below.

Indicator	Unwanted Condition	Wanted Condition	Calculation	Result
Water Supply Source	All Imported	All local & Recycled	Proportion of total water use to local and recycled use	71
Per Capita Water Use	SB x7-7 2010 Baseline	SB x7-7 Goal	Because reported data puts per capita consumption above the 2010 baseline for the South Coast region, this indicator scores a zero grade. Future assessments will describe the progress towards the 2020 goals.	56
Local Reserves	Deficit of supply during local multi-year drought	Sufficient supply available during local multi-year drought	Ultimate demand during sequential three-year droughts as compared to supplies during multi-year drought	1
Sustainable Water Rates	No retailers using sustainable rates	All retailers using sustainable rates	Number of water retailers using sustainable rates compared to all water retailers	52
Carbon footprint of energy in water	Energy use greater than 5% over the five year average	Energy use lower than the five year average	Five year average CO2 emission divided by 2012 emissions as compared to range of conditions	32

3.2 Hydrology

Manage at the watershed scale for preservation and enhancement of the natural hydrology to benefit human and natural communities

The most effective tool in sustainable local water management is the existing natural systems of the watershed. Rain and snow that fall in the mountains, the native plants and soils that use or hold that water, and the dynamic systems of water and material flow in the streams are all key players in the health of the watershed. And, each of these components together provides the services that both people and other species need to thrive.

Four indicators were examined for this goal. Two are related to the physical processes, one about management response to changing physical processes, and one related to the extent and health of natural habitats. Critical to natural hydrology is the least impactful conversions of landscape to hardscape. At the watershed scale, it takes only a small area if land converted to effective impervious surfaces before negative impacts to the hydrology are experienced. The streams themselves also must be maintained in a natural condition as much as is feasible and safe. Connected habitat in streams stands here as indicating the extent to which the hydrology of the watershed is natural.

The Santa Ana watershed benefits from a strong majority of streams remaining with natural substrates. The watershed itself has significant areas of impervious landscape, however because no dataset exists to understand effective imperviousness, this indicator was not scored. Future assessments must work to understand not simply the existence of impervious landscape, but rather if that landscape is producing the well-understood negative consequences of additional volumes and rates of runoff during storms, and in dry weather.

Coastal impacts from climate change must be considered within the management of a healthy watershed. The Santa Ana watershed is home to communities, industry and other economic assets that will be impacted by rising sea levels. The indicator measured here includes a metric for mitigation of additional green-house-gas emissions, admitting that the Santa Ana watershed has only a proportionally small role in this global challenge. More importantly though is for the watershed to begin managing the coastline to be more resilient to a rising sea.

Aquatic habitat fragmentation reveals the impacts of in-stream infrastructure as a barrier to animal and insect transit, and to a lesser extent the hydrogeomorphic processes of a natural stream. In this case the Santa Ana watershed has challenges of fragmentation in slightly over half of the subwatersheds.

Indicator	**Unwanted Condition**	**Wanted Condition**	**Calculation**	**Result**
Natural stream beds	All Artificial Beds	All Natural Beds	Percent of stream miles with natural beds	69
Imperviousness of watershed	Greater than 5% effective impervious land cover in watershed	Less than 5% effective impervious land cover in watershed	Analysis of spatial data reflecting impervious. Because effective impervious data is not available, this indicator was calculated but not scored (see appendix)	Incomp lete
Resiliency to Coastal Impacts of Seal Level Rise	No preparedness	A coastline prepared for variable sea level increases	The indicator is proposed as looking forward, therefore no assessment of existing condition was carried out.	N/A
Connected Aquatic Habitat	100% of HUC 12 watersheds >30% fragmentation or any HUC 12	All HUC 12 watersheds 0% fragmented	Of 74 HUC 12 watersheds, percent below 30% fragmentation, zero score if any watershed above 50%	57

	watershed >50% fragmented			

3.3 Open Spaces

Preserve and enhance the ecosystem services provided by open space and habitat within the watershed

Having open spaces for habitat, recreation, and respite are all goals of the statewide integrated water management efforts. A commitment to these goals has long been a component of the managers within the Santa Ana Watershed.

This goal examined four indicators that help understand the breadth of value that healthy open space can bring. An analysis of open space for recreation revealed that different areas of the watershed have different opportunities and challenges for recreation. Several of the large open space recreational facilities count their users, and understanding better if these facilities are either over- or under-subscribed is an important tool for managers. Open space needs to be protected, and kept healthy through the removal of invasive species that damage their ability to provide value. The last two indicators confirm that invasives are being treated, and that critical open space is being sheltered from over-development.

In the Santa Ana watershed, a strong majority of residents have ½ mile access to recreational open space. Within the watershed, invasive plant management has been undertaken, but data was insufficient to express acres of invasives treated or removed. Within the upper watershed the two National Forests account for a large area of protected land, and outside the forest many of the riparian corridors have some sort of habitat designation that provides protection.

Indicator	Unwanted Condition	Wanted Condition	Calculation	Result
Access to open space per capita	No residents within 1/2 mile	All residents within 1/2 mile	Census block centroids within 1/2 mile of recreational open space	70
Invasive Species Management	Invasives unknown and/or untreated	Invasives assessed and being treated	Extent of invasive species assessment and extent of treatment programs	Incomp lete
Protected lands	Remaining Native Habitat unprotected from development	All remaining native habitat protected from development	Proportion of open space that has protected status	69

3.4 Beneficial Uses

Protect beneficial uses to ensure high quality water for human and natural communities

Beneficial Uses Designated By the Santa Ana Basin Plan	
Municipal and Domestic Supply	Warm Freshwater Habitat
Agricultural Supply	Cold Freshwater Habitat
Industrial Service Supply	Preservation of Biological Habitat
Industrial Process Supply	Wildlife Habitat
Ground Water Recharge	Rare Threatened or Endangered Species
Navigation	Spawning
Hydropower Generation	Reproduction, and/or Early Development
Water Contact Recreation	Marine Habitat
Non-contact Water Recreation	Shellfish Harvesting
Commercial and Sport Fishing	

From the February 2008 Basin Plan Update, www.waterboards.ca.gov/santaana

The Clean Water Act uses the term "Beneficial Uses" to describe the water quality standards for each water body. Depending on the historical, present or potential use of the water, the standards are set for particular pollutants related to those uses. Water bodies that are impaired from meeting their beneficial uses for one or many pollutants are added to a list, termed the 303(d) list (CWA section), and regulatory agencies begin formulating a Total Maximum Daily Load (TMDL) for the pollutant(s) causing the impairment. In this goal the explicit link to regulatory requirements is made related to water quality.

Beneficial uses in the Santa Ana watershed are designated by the Santa Ana Regional Water Quality Control Board in a document, and monitoring is undertaken by many agencies through permit or other regulatory requirement. For this goal six indicators were analyzed, each addressing a different beneficial use related to groundwater quality, surface water quality, biological aquatic condition, and measures of salinity in the ground and surface water.

The Basin Monitoring Program released a report in 2012 finding that for Reach 1B of Chino Creek experienced some exceedances in various water quality constituents compared to the Basin Plan Objectives as did Reaches 2, 3, and 4 of the Santa Ana River and Reach 5 was not monitored for lack of stream flow. Several tributary streams or water bodies along Reach 3 also experienced some exceedances to the Basin Plan objectives.

Challenges of salinity in groundwater are considered by analyzing the number of groundwater management areas that are estimated to have a negative assimilative capacity or deteriorating water quality as compared to the historical ambient water quality in the 2012 Recomputation of Ambient Water Quality in the Santa Ana Watershed for the Period 1990-2009 completed by Wildermuth Environmental Inc. It shows that 19 of the 41 management areas have a negative assimilative capacity for total dissolved solids. Monitoring of water quality at the outfalls from wastewater treatment plants is a key piece of their National Pollutant Discharge Elimination System permits.

Water-contact recreation is present in many locations in the watershed, and monitoring that water for the presence of bacteria harmful to human health is conducted along the beaches of the watershed, however a comprehensive effort at inland freshwater swimming sites has not been conducted.

Biological condition in streams is a proxy for the quality of the water, as degraded water conditions will be harmful to plants, animals and insects that live in the streams. Using the California Stream Condition Index, about half of the HUC 12 watersheds were scored. Additional monitoring is called for to expand the understanding of in-stream biological condition in the Santa Ana watershed.

Indicator	Unwanted Condition	Wanted Condition	Calculation	Result
Watershed-wide water quality	Any reach out of compliance with Basin Plan	All reaches in compliance with Basin Plan	Proportion of three reaches and associated tributaries considered in compliance with Basin Plan	75
Groundwater salinity	All gw management zones basins with exceedances	No gw management zones with exceedances	Proportion of management zones with negative assimilative capacity or deteriorating levels for TDS	46
Discharge water quality	One or more exceedances at all monitored outfalls	No Exceedances at monitored outfalls	Wastewater Treatment Plants monitor outfall water quality. Number of exceedances against total number of sampling	Incomplete
Recreational water quality	More than 10% of samples taken showing exceedances	No samples showing exceedances	Number of samples for bacteria taken from locations with known water contact recreation that showed exceedances	Incomplete
Biological Condition in streams	All streams with California Stream Condition Index scores below 0.72	All streams with CSCI scores between 0.72 & 1.21 (max)	Using existing CSCI station scores, what proportion of graded HUC 12 watersheds have lower than 0.72 CSCI scores (18 of 36)	50

3.5 Effective & Efficient Management

Accomplish effective, equitable and collaborative integrated watershed management in a cost-effective manner

This goal is the most forward thinking in this assessment, not because the goal is a new idea, but rather that the OWOW group has decided to specifically measure progress towards this goal. The sustainability and equity of integrated water management is important to the long-term successes desired, and with this goal the Santa Ana watershed is asking an important question.

Despite the laudable intent of this goal, the challenge of indicating the effectiveness, equitability, and thoroughness of the collaborative process are extremely challenging. Researchers engaged with colleagues in many related efforts in the state and elsewhere, and found that many are struggling to engage meaningful indicators of effective collaboration.

Below are two tables, one reflecting the draft indicators considered by the Pillars and SAWPA which were not scored, and a table reflecting the concepts about effective management that are being incorporated into the DWR Water Plan Update 2013.

Indicator	**Unwanted Condition**	**Wanted Condition**	**Calculation**	**Result**
OWOW Participation Statistics	Lack of representation from area, sector, or community	All sectors, areas, and communities represented	Insufficient data	Incomplete
Performance of OWOW 1.0 Projects	No OWOW 1.0 selected projects meeting stated goals	All OWOW 1.0 selected projects meeting stated goals	Insufficient Data	Incomplete
Cost-effectiveness of management	An indicator of the cost-effectiveness of management was discussed at length. The scope and a sufficient dataset could not be identified. Future work should consider further how to express this, as it critical to the selected goal.			

DWR Water Plan Update 2013 concepts for effective management tracking
The ease or barriers to flow of the process from data need, collection, analysis, decision-making, implementation, and results
Local jurisdictions and geographies sufficiency of data for decision-making
Public reporting system for data and results of analysis as well as methods used

Standardized methods for data collection and reporting and minimize collection biases
Data sharing and distribution
Communication of uncertainty in assessments and decision-making
Collaboration between scientists and policy makers to understand data and communication needs
Supports adaptation and resilience to climate change

4.0 Summary

This report describes the goals for the Santa Ana River Watershed as highlighted by the OWOW Pillars and SAWPA. For each goal, a series of indicators help describe the movement towards those goals. As is customary in California coastal watersheds, there are signs of challenges and progress within each goal. Conditions are in-general degraded from a natural system, however, management efforts to restore and enhance are found throughout the process.

Among the findings there is a call for future work to gather new or more robust datasets related to watershed management. Most significantly, additional effort is needed to better resolve the performance metrics of the management system itself. The goal of inclusive, equitable, and collaborative management is an important part of OWOW, and resolving how to measure the effort towards that goal is a critical next step.

This assessment can be repeated in a time-interval to include a set of metrics that express trends. This assessment here is a snapshot of the current day in the Santa Ana watershed, and many of the goals are specifically designed to encourage progress. In five years, perhaps sooner, this assessment can be repeated to uncover laudable progress, and spots where efforts should be redoubled.

Indicator-Specific Results of Regional Pilot Test of the Sustainability Indicators Framework

OWOW Sustainability Goal 1: Maintain reliable and resilient water supplies and reduce dependency on imported water

Indicator 1: Proportions of total water use to imported water use and recycled water use

What is it?

Semi-arid environments like Southern California must move from high-demand water use with a reliance on imported water to lower-demand, high-efficiency water use that primarily relies on local and recycled water supplies. For the Santa Ana watershed this suggests additional use of recycled water, a further push towards water use efficiency, clean-up of tainted or nonpotable waters through treatments processes such as groundwater desalination and additional rain water and snowmelt capture as supplies.

Why is it Important?

The reliability of imported water supplies are threatened by climate change, source demand, an increased awareness of environmental costs, and the expense of system operations and maintenance. It is critical to provide an assessment of the path towards making the Santa Ana watershed resilient to these changes.

What is the target or desired condition?

Regional self-reliance is the target condition for water supplies in the Santa Ana watershed. This includes the increase of rain and snow melt capture as supply, the increase of recycled water use, clean up and use of tainted or nonpotable water and the reduction of water demand. By decreasing demand and increasing local supplies, the communities within the Santa Ana watershed can become self-sufficient.

What can influence or stress condition?

This indicator is sensitive to the sources of water, and the use of water within the watershed. In the effort to increase local supplies, a changing climate, infrastructure investments, regulatory changes, and behavior of people can all have significant influence. Climate variability can also play a role, as the frequency and intensity of storms can impact the ability to provide a sufficient local supply.

Basis of calculation and use

The 2010 Urban Water Management Plans submitted for the agencies within the Santa Ana Watershed each calculate the percentage of the total water use that was supplied from imported water. If all water were derived from local sources, this would be 0% imported, with a score of 100. In this case, 29% is imported (2010 numbers), leading to a score of 71.

What did we find out/How are we doing?

The summary of reports show that 29% of water used was supplied from imported sources in 2010. The reports make predictions for future years, and though it was not associated with the score of this indicator, it is worth noting that the prediction is for the region to become more reliant on imported water (35% in 2035) Though recycled water is also seen as becoming a larger percentage of the supply, it appears that the growth in demand is seen as requiring additional imported water supplies.

How sure are we about our findings (Things to keep in mind)

By using Urban Watershed Management Plans, this indicator relies on the regulatory reporting requirements that the retail water providers must meet. However, only retailers that provide more than 3,000 acre-feet per year or have more than 3000 connections are required to provide these plans to the State. This means that portions of the Santa Ana watershed are not represented in the data used.

Technical Information

Data Sources

Data used to evaluate the "Proportions of total water use to imported water use and recycled water use", include 2010 Urban Water Plans submitted within the Santa Ana River Watershed. These reports summarize anticipated supplies and demands for the years 2010 to 2035 for water retailers located within the Santa Ana River watershed.

The specific data used in this analysis is a summary of imported and recycled water use as a proportion of total water use for agencies as reported in their 2010 Urban Water Management Plan submitted to the California Department of Water Resources (see Table 3).

Table 3. Proportions of Total Water Use to Imported Water Use

Proportions of Total Water Use to Imported Water Use and Recycled Water Use						
	2010	2015	2020	2025	2030	2035
% Imported	29%	29%	30%	32%	33%	35%
% Recycled	6%	8%	9%	10%	10%	10%

Indicator 2: Per capita water use

What is it?

The Governor's Office of California issued the 20x2020 Water Conservation Plan in February 2010 that calls for a statewide reduction in water use, 20% overall by the year 2020 (California Department of Water Resources, et. al., 2010). Current statewide per capita water use is 193 gallons per day (gpd), and the 2020 target is 154 gpd. Table 4 below, taken from within the plan itself, reflects the baseline conditions and the targets laid out in the plan for the various regions of the state. Residents of the Santa Ana River Watershed reside within Region 4.

The plan includes regional interim targets for 2015, and final targets for 2020 that if met in each region will take the entire state to the goal of using 20% less water. This "road- map" will help the state achieve a more sustainable water practice, in response to multiple issues as laid out in the Plan's executive summary:

- Reduced stress on the environment of the Sacramento-San Joaquin Delta
- Delayed capital cost of new infrastructure to treat and deliver water
- Reduced demand for wastewater treatment, including capital costs and ongoing treatment costs
- Reduced water-related energy demands and associated greenhouse gas emissions
- Improved ability to meet environmental needs
- Improvements in the quality of receiving waters related to reduced discharge
- Reduced use of fertilizers, pesticides, and herbicides and reduced escape of these chemicals into surface waters through use of native plants and low water using varieties, reduced production of green waste, and improved habitat value of urban landscapes
- Enhanced flexibility in water management and delivery systems, especially during dry periods
- Better capacity to meet the challenge of California's growing population.

For the South Coast region, the plan calls for a decrease from the current all-uses 180 GPD to a goal of 149 GPD. An interim target of 165 GPD is sought for the year 2015.

Why is it Important?

As the 20x2020 plan encourages, decreasing per capita water use will have positive influence on a number of issues facing the watershed, the region, and the State. How water is used around the home/business and outdoors suggests attitudes towards the availability of water, and the associated value of particular water practice (landscaping, washing sidewalks and driveways, etc.) California's water resources are finite and need to be managed for long term sustainability.

What is the target or desired condition?

For Region 4, which includes the Santa Ana watershed, the overall goal is 165 GPD by 2015, and 149 GPD by 2020. For residential-only, the baseline is 126gpd, however the 20x2020 Water Conservation Plan[3] does not call-out residential only goals. Using the overall baseline and goals, the Region four targets are an 8.3% reduction by 2015, and a 17.2% reduction by 2020. Using 126gpd as baseline, the 2015 target for residential-only in this region is 116gpd, and the 2020 target is 104gpd.

What can influence or stress the condition?

Per capita water usage is a statistic that includes water use within all the different sectors of the economy in the numerator, but only takes into account the residential population of the area in the denominator of the metric. This can make comparing regions challenging, as a heavily industrial or agricultural area will have large water needs and small populations, making the per capita number quite large. Even within sectors there can be great variability. Residential areas, for instance, can have significantly different patterns of water use, where the smaller plots in coastal subdivisions use much less water than do the more affluent, large-parcel single-family homes in the foothill communities.

The 20x2020 plan works at a broad regional scale, making many of the concerns addressed above not relevant. At the watershed scale, as in this analysis, it is possible to see the differences in land-use and affluence in the various data provided by the water companies. By creating a watershed-wide average, these variations should play a less significant role.

When comparing the water companies to one another, using the per capita rate without an awareness of either the raw population or total water usage values would be unfair. The few companies whose per capita numbers are very large are serving a very small portion of the population of the watershed. This suggests that efforts to make further changes be tailored to the users who are contributing these high values.

Basis of calculation and use

For this indicator, the reported per capita rates were normalized to the "Gross Water Use" (Method 1)[4] calculation provided by the SB x7-7 legislation, where residential use is split from commercial and industrial use, and the residential water use is used to calculate per capita rates. Each agency was then assessed for being over the baseline of 126gpd, below the baseline but above the target of 104gpd, or below the target of 104gpd. Each of these categories then counted population, yielding percentages of the population in each. For the indicator, each category was provided a weighting, where above baseline was zero, below baseline but above target was 0.5,

[3] http://www.water.ca.gov/wateruseefficiency/sb7/docs/20x2020plan.pdf
[4] http://www.water.ca.gov/wateruseefficiency/sb7/docs/MethodologiesCalculatingBaseline_Final_03_01_2011.pdf

and below target was 1. By multiplying the percentage times 100 and the weighting, we produced a score between 0 (no people under baseline) and 100 (all people below the target).

What did we find out/How are we doing?

About 8.9 million people use 1.02 billion gallons per day, providing an estimate of 114 gallons per day per person within the watershed. This value below the baseline and the 2015 interim target for the watershed, however, is still above the 2020 target.

Table 4. Water use above and below target (gpd per capita).

Condition	Population represented in dataset	Percent of Total Population	Weighting	Points
Above Baseline (126gpd, residential only)	3,047,812	34%	0	0
Below baseline, above target (104gpd, residential only)	1,626,371	18%	0.5	9.13
Below target	4,227,807	47%	1	47.49
Totals	8,901,990	100%	Score:	**56.63**

How sure are we about our findings (Things to keep in mind)

The data used for this report relies on reporting from the various agencies, and has been normalized to residential-only values using Method 1. These calculations are sound, however, the 20x2020 goals are not solely for residential users. Future analyses of this indicator should move to calculate all water use, including commercial, industrial and agricultural alongside residential.

Indicator 3: Local water supply reserves to meet ultimate needs

What is it?

This indicator challenges the resiliency of the water supply in the Santa Ana watershed by considering the ultimate need as compared to the water supply available during a multi-year drought. The drought considered here is a local one in the watershed.

Why is it Important?

The Santa Ana watershed relies on imported water in a normal year, and increases that reliance during drought conditions. Regional self-reliance should include planning for reduction in imported supplies through drought conditions within the Colorado River Basin or along the Sierra Nevada Mountains. So too, the State Water Project and the Sacramento Bay Delta system are both vulnerable to earthquake damage and reliability planning should therefore be incorporated for any potential scarcity effects might develop due to source damage.

What is the target or desired condition?

For this assessment the management scenario analyzed was a multi-year (avg. 3 year drought under a 10 year hydrologic cycle) local drought. The desired condition is that the ultimate demands during that scenario will be met with a sufficient supply.

What can influence or stress condition?

The need for a local reserve is predicated on decisions about what ultimate demand is and the contours of the scenario that will push the region to rely on that supply. The ability to hold a local reserve also relies on groundwater basin capacity and groundwater quality, in addition to surface storage facilities. The calculation of ultimate demand also can be influenced by water use efficiency efforts.

Basis of calculation and use

Values for available water supplies and demands were taken from the Urban Water Management Plans, and calculated (in a way referenced in that complex spreadsheet). The data shows that a local multi-year drought will not drive the watershed into a deficit in supply.

Table 5. Average Annual Supplies and Demands

Average Year Supplies to meet Ultimate Demands	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**
Total Demands	279,658	294,826	308,001	337,200	361,938	380,416
Local Surface Water	51,150	53,197	53,197	53,197	53,197	53,197
Groundwater	215,409	216,163	224,336	226,095	227,913	229,779
Imported Water	80,159	85,638	85,398	90,895	96,318	100,808
Recycled Water	7,764	13,574	16,186	22,973	30,116	36,393
Drought Ordinances	-	944	3,039	4,141	5,230	5,914
Total Supplies	354,483	369,516	382,155	397,301	412,775	426,091
Surplus/Deficit	74,825	74,690	74,155	60,101	50,837	45,675
Multi-Year Drought Supplies to meet Ultimate Demands	2010	2015	2020	2025	2030	2035
Total Demands	290,934	303,755	314,503	337,744	355,687	368,391
Local Surface Water	24,575	26,622	26,622	26,622	26,622	26,622

Groundwater	223,747	220,155	229,663	234,850	238,385	240,103
Imported Water	81,859	86,738	88,316	95,572	101,234	105,690
Recycled Water	7,764	13,374	15,986	22,773	29,916	36,193
Drought Ordinances	-	944	3,039	4,141	5,230	5,914
Total Supplies	337,945	347,833	363,626	383,958	401,388	414,522
Surplus/Deficit	47,010	44,079	49,123	46,215	45,701	46,131

What did we find out/How are we doing?

Water supply within the watershed is managed properly to withstand a local multi-year drought. However, it is critical that future assessments consider other scenarios for managing against multi-year disruptions in supply. Concurrent droughts for both imported sources, and damage to one of the supply systems, are both realistic scenarios that would impact the values used in this indicator. It is unlikely, for example that the Santa Ana watershed is prepared for a long disruption of the State Water Project caused by a seismic failure of levees in the Bay Delta. So too, a decrease in available supplies from the Colorado River Aqueduct and the State Water Project due to droughts within both systems would strain Santa Ana watershed supplies.

How sure are we about our findings (Things to keep in mind)

By using Urban Watershed Management Plans, this indicator relies on the regulatory reporting requirements that the retail water providers must meet. However, only retailers that provide more than 3,000 acre-feet per year or have more than 3000 connections are required to provide these plans to the State. This means that portions of the Santa Ana watershed are not represented in the data used.

Technical Information

Data Sources

Data used to evaluate the “Proportion of stored water to stored water scenario”, include 2010 Urban Water Plans submitted within the Santa Ana River Watershed. These reports summarize anticipated supplies and demands for the years 2010 to 2035 for water retailers located within the Santa Ana River watershed.

The specific data used in this analysis is a summary of proportions of water stored to multiple dry year storage scenarios for agencies as reported in their 2010 Urban Water Management Plan submitted to the California Department of Water Resources (see Table 5 and Table 6).

Table 6. Drought Conditions vs. Average Year Conditions

Drought Conditions vs. Average Year Conditions												
	2010		2015		2020		2025		2030		2035	
Supply	(287,483)	82%	8,900	101%	5,100	100%	7,900	100%	4,400	100%	100	100%
Demand	1,500	100%	60,700	104%	57,900	104%	54,200	103%	48,900	103%	45,500	103%

Indicator 4: Adoption of Sustainable Water rates

What is it?

Sustainable Water rates encourage water use efficiency by charging increasing larger per-volume rates to high-volume users. SAWPA has committed to encouraging this management approach within the IRWM process.

Why is it Important?

Southern California has very high per-capita water use when compared to global regions with similar climate and economy. Using a pricing structure to better resolve the costs of high water demand will encourage water use efficiency, and will generate resources that can be spent on efficiency measures elsewhere.

What is the target or desired condition?

The target for the Santa Ana watershed is to have every retail water provider using a sustainable water rate structure.

What can influence or stress condition?

This management decision must be made by each agency. Management structures, authorizing language and user education can all play a role in implementation of these ideas.

Basis of calculation and use

SAWPA staff polled water retailers in the Santa Ana watershed to identify agencies employing sustainable water rates.

What did we find out/How are we doing?

The results are summarized in Table 7 below:

Table 7. Sustainable Water Rate Adoption

County	Total Agencies	Agencies with Tiered Rates	% Agencies by County
Riverside	18	14	78%
Orange	24	11	46%
San Bernardino	20	7	35%
Total	**62**	**32**	**51.61%**

How sure are we about our findings (Things to keep in mind)

At the time of the survey, these data were certain. Because management decisions can be made quickly, this indicator must be updated with frequent assessments of the watershed.

Indicator 5: Water Availability and Stress

What is it?

Water availability is key to stable human societies. Water stress is defined as the ratio of water withdrawals to the water available from natural and artificial sources (Reig et al., 2013). Water withdrawals are for human uses (e.g., agricultural, urban, and industrial). The water available may be from surface and/or ground sources and is the total natural water minus any upstream uses. Groundwater stress is defined as the ratio of groundwater withdrawal to recharge rate for a specific groundwater basin.

Four metrics were included from the World Resources Institute (WRI) Aqueduct 2.0 project: A) Available blue water, the amount of water available for withdrawal and ecosystem needs, B) Baseline water stress, the ratio of water withdrawn to water available, C) Upstream protected lands, the proportion of the watershed in protected status, and D) Return flow ratio, the proportion of available water that was previously used upstream and potentially of lower quality. For each metric, an impact category was determined (e.g., “high”) for broad areas of the world. It is likely that these metrics could be calculated more accurately at a fine scale (e.g., river sub-watershed or municipality).

Because these important metrics were developed by an outside entity and there is no way to determine how frequently they will be updated, these metrics and this indicator should be re-visited and a strategy developed for repeating them.

Why is it Important?

Tracking the relative availability of water and stresses on water sources is important for understanding water sustainability. In California, there is no commonly-used system of comparing water use to water availability. This is recognized globally as a very important comparison to make. Other important indicators of water supply reliability are protection of source waters and the proportion of water supply that has been previously used and returned to the local water cycle.

What is the target or desired condition?

The target conditions for all indicators were identical to those described by the World Resources Institute in the Aqueduct project (Reig et al., 2013).

What can influence or stress condition?

There are many influences on water availability and use and the ratio of these two processes. Natural variability in precipitation at annual and decadal scales is one of the most important influences on water availability, though not necessarily on use that originates from groundwater. Another influence on water availability is the rate of upstream use for human purposes, including maintaining ecological processes.

Basis of calculation and use

The World Resources Institute recently described global water and water use conditions (Reig et al., 2013), using score categories of low to extremely high to describe the range of good ("low", 0-1) to poor or stressed ("extremely high", 4-5) conditions. These scoring ranges and categories were adopted for use here. Each indicator was compared to threshold values and normalized to a scale of minimum value to maximum value.

What did we find out/How are we doing?

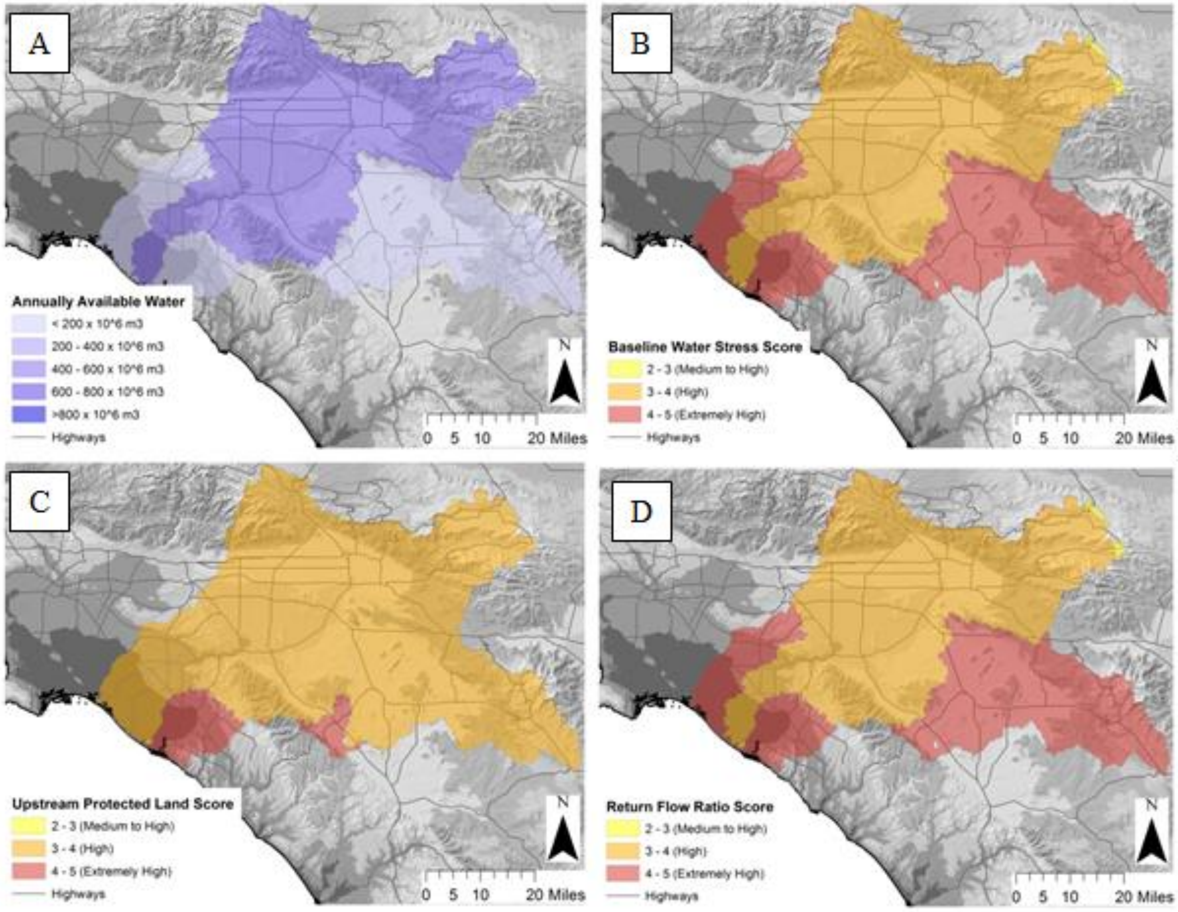

Figure 8. Water Availability and Stress Map

Figure 8 shows conditions for various WRI indicators for the SAWPA service area. A) Water availability, the amount of water available for withdrawal and ecosystem needs (units = cubic meters of water), B) Baseline water stress, the ratio of water withdrawn to water available (units = normalized water stress), C) Upstream protected lands, the proportion of the watershed in protected status (units = normalized score), and D) Return flow ratio, the proportion of available water that was previously used upstream and potentially of lower quality (units = normalized score).

Temporal and spatial resolution

Time ranges for each indicator varied, with the complete range of data used between 1901 and 2012. Exact date ranges are in WRI's metadata report[5]. The indicators are best interpreted as recently accurate and averaged over a year.

Spatial resolution ranged from the river basin (e.g., Santa Ana River watershed) to whole countries. The indicators are most accurate at the scale of the SAWPA service area.

How sure are we about our findings (Things to keep in mind)

The spatial and temporal scales of the indicator data and analyses were fairly general relative to the scale of the SAWPA service area and annual changes in water. In addition, the data were derived from global sources rather than sources specific to California or SAWPA. It is likely that the conclusions are accurate at the SAWPA service area scale, but distinctions within this area and within individual years may not be meaningful.

Technical Information

Data Sources

All data were derived from the World Resources Institute, Aqueduct Project[6]. The WRI in turn obtained data from a wide range of other sources around the world. The descriptions of data the WRI analysts used are in a metadata report (Gassert et al., 2013) and are shown in summary form here (Table 8).

Table 8. Source Data for WRI Aqueduct Project

Indicator	Timeframe	Spatial resolution	Sources
1) Available blue water a) total water b) water use	a) 1950 – 2008 b) 2004	a) 1 degree raster b) regions (e.g., Southern California)	a) Global Land Data Assimilation System Version 2 (GLDAS-2), 2012. http://disc.sci.gsfc.nasa.gov/hydrology/data-holdings b) World Water Resources at the Beginning of the Twenty-First Century, International Hydrology Series, Cambridge University Press. I.A. Shiklomanov and John C. Rodda eds.
2) Baseline water stress (combination of available water and	2008 - 2010	Country	Food and Agriculture Organization of the United Nations (FAO), FAOAqUASTAT http://www.fao.org/nr/water/aquastat/dbase/index.stm

[5] http://aqueduct.wri.org/download/metadata-aqueduct-global-maps-20
[6] http://aqueduct.wri.org/

withdrawals)			
3) Upstream protected lands	2010	Individual dams	Global Reservoir and Dam (GRanD) Database Version 1.1, 2011; http://atlas.gwsp.org/index.php?option=com_content
4) Return flow ratio (combination of available blue water and water use)	2004	regions (e.g., Southern California)	Global Land Data Assimilation System Version 2 (GLDAS-2), 2012. http://disc.sci.gsfc.nasa.gov/hydrology/data-holdings World Water Resources at the Beginning of the Twenty-First Century, International Hydrology Series, Cambridge University Press. I.A. Shiklomanov and John C. Rodda eds.

Data Transformations and Analysis

Global data were clipped using the SAWPA administrative boundary. No alteration of the values in the base data were made. The base conditions (e.g., blue water available) and indicator conditions (e.g., baseline water stress) are presented in the original form. In every case, "low" represents low risk or stress and "extremely high" represents the highest risk or stress. The indicator normalization approach used by WRI is similar to the approach used by the California Water Plan Sustainability Indicator Framework in that indicator values are compared to thresholds established for each parameter.

Indicator 6: Annual water resource energy use compared to 5-year rolling average

What is it?

The embedded energy and carbon emissions within the system of water resource provisioning and consumption have costs to the watershed. The methods used account for embodied energy and the subsequent GHG emissions of water consumption in a study area. Figure 9 illustrates the different energy consuming processes involved in the delivery and treatment of water. End-use of water is not considered in this analysis; for example, energy used for heating water in the home.

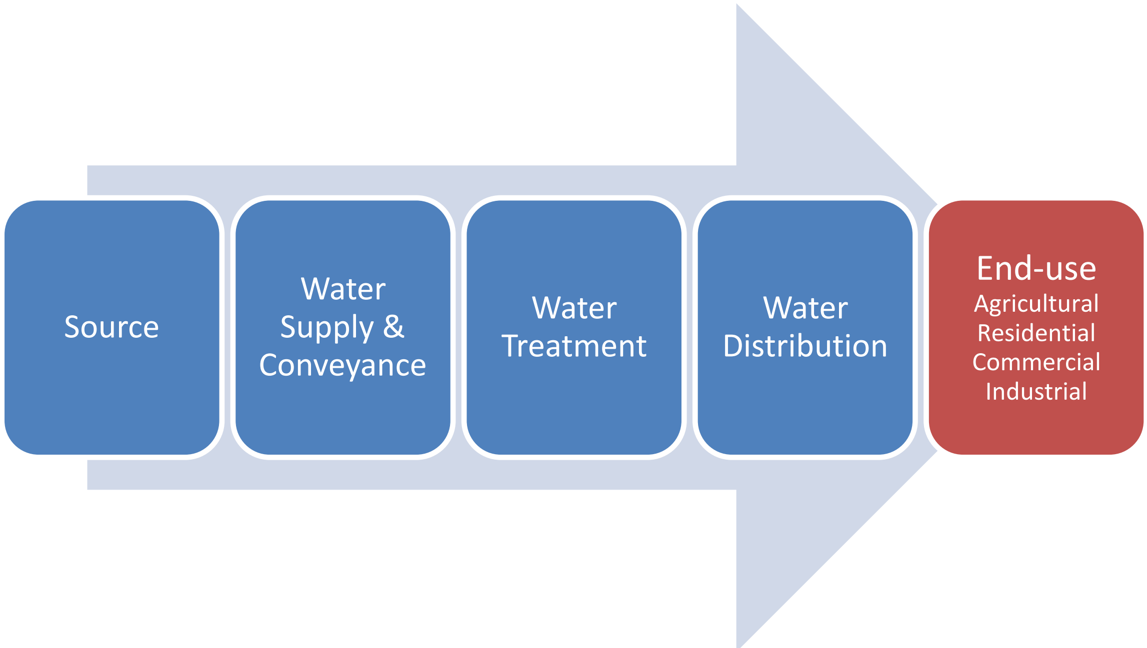

Figure 9. Energy Consuming Process in the Delivery and Treatment of Water (red not included in analysis).

Why is it Important?

The water-energy nexus is being considered for its climate impacts, but also as a technique for lowering costs to consumers of water. Local supplies require less power to manage, and therefore reduce carbon emissions. The water resource provisioning of California is among the largest users of electricity in the State, and reducing the impact of that power generation could be a critical piece of both mitigation and adaptation of climate change.

What is the target or desired condition?

The target for the Santa Ana watershed is to have an annual reduction over the five-year rolling average in greenhouse gas emissions related to the water resource provisioning system.

What can influence or stress condition?

The energy intensity of various water supplies must be considered. State Water Project, for instance, has a much higher embedded energy profile than does the Colorado River Aqueduct. Local groundwater has significantly lower embedded energy than either of these imported sources. Also, the use of highly treated potable water for non-potable tasks (industrial processes, sanitary uses, etc.) spends energy needlessly.

Basis of calculation and use

To score this indicator, the estimate of CO_2 equivalent emissions related to water consumption provided for 2010 was compared to the five-year average. With the goal of a reduction, the "worst case" was set at a 5% increase above the five-year average.

Table 9. MMT CO_2 Equivalent in Water Consumption

Year	Million Metric Tons of CO2 equivalent
2008	1.03
2009	1.05
2010	1.06
2011	1.08
2012	1.10

What did we find out/How are we doing?

2012 shows a 3. 4% increase above the five-year average of 1.064 MMTE. Worst case would be an increase greater than 5% above the five-year average. The goal of any value below the 5-year average.

Case	Percent above 5-year rolling average	Score
Best case	<= 0%	100
Example	2.5%	50
This assessment	3.4%	32
Worst case	>=5%	0

How sure are we about our findings (Things to keep in mind)

This analysis used draft output from a GHG Emissions Calculator developed by the United States Department of the Interior Bureau of Reclamation. The calculator allows users to implement this method in order to easily and quickly evaluate how their water management decisions affect their water demand, energy use, and GHG emissions. A full technical report on the GHG Emissions Calculator will be published by fall 2013.

Technical Information

Study area specific energy consumed per unit of water for each process of the water system was utilized. If site specific information was not available, southern California defaults were used. Default utility specific emission factors were obtained from the California Climate Action Registry Power/Utility Protocol reports. Annual average electricity emission factors came from the California Air Resources Board Greenhouse Gas Inventory (2007), and eGRID (2009).

Equation 1 depicts how total annual CO_2e emissions are calculated:

$$\text{Annual } CO_2\text{e emissions} = \text{Extraction} + \text{Conveyance} + \text{Treatment} + \text{Distribution}$$

Where:

$$\text{Extraction} = \Sigma\,(\text{Source Percentage} * \text{Population} * \text{Per Capita Use} * \text{Process Energy Intensity}_{\text{GW Extraction}}) * \text{Energy Emissions Factor} * \text{Unit Conversions}$$

And:

$$\text{Conveyance} = \Sigma\,(\text{Source Percentage} * \text{Population} * \text{Per Capita Use} * \text{Process Energy Intensity}_{\text{Conveyance}}) * \text{Energy Emissions Factor} * \text{Unit Conversions}$$

And:

$$\text{Treatment} = \Sigma\,(\text{Source Percentage} * \text{Population} * \text{Per Capita Use} * \text{Process Energy Intensity}_{\text{Treatment}}) * \text{Energy Emissions Factor} * \text{Unit Conversions}$$

And:

$$\text{Distribution} = \Sigma\,(\text{Source Percentage} * \text{Population} * \text{Per Capita Use} * \text{Process Energy Intensity}_{\text{Distribution}}) * \text{Energy Emissions Factor} * \text{Unit Conversions}$$

OWOW Sustainability Goal 2: Manage at the watershed scale for preservation and enhancement of the natural hydrology to benefit human and natural communities

Indicator 7: Percent of stream network with natural substrate ("soft-bottom")

What is it?

This indicator describes the condition of the substrate of the streams in the Santa Ana watershed outside the National Forests. Having natural substrate (soft-bottom) permits the natural function for sediment and water flows, as well as influent and effluent conditions where groundwater and surface flows interact.

Why is it Important?

Maintaining the link between surface water and groundwater is a critical component of a local supply management effort. So too, natural streams provide habitat and disturbance patterns that are relied upon by native species.

What is the target or desired condition?

The target for the Santa Ana watershed is to manage all streams with natural substrates.

What can influence or stress condition?

Flood risk management within the twentieth century was pursued in a single-purpose manner, resulting in many streams being hardened. This in turn resulted in land-use decisions that relied upon the hardened channel. As future efforts consider the removal of hardening, there will be challenges to properly balance the desire for naturally functioning streams and the limits caused by risk.

Basis of calculation and use

The extent of streams and their associated substrate was estimated for each county and the entire Santa Ana River watershed based upon available GIS layers of natural and modified streams.

The results of this analysis are summarized below:

Table 10. Extent of Natural Stream Substrate

	EMWD	IEUA	OCWD	SBVMWD	WMWD	SAWPA
Modified Channels	267	196	264	186	348	1317
National Hydrography Dataset	512	250	326	539	632	4261
Percent Modified	52.1	78.4	81.0	34.5	55.1	30.9
Percent Natural	47.9	21.6	19.0	65.5	44.9	69.1

What did we find out/How are we doing?

Most streams within the Santa Ana watershed have a natural substrate.

How sure are we about our findings (Things to keep in mind)

A complete dataset was not available to make this analysis, however it is likely that the score is appropriate for the watershed. The protection of the upper watershed by the National Forests is significant to the region.

Technical Information

Data Sources

Modified Channels, National Hydrography Dataset

Indicator 8: Proportion of watershed covered with impervious surfaces, including pavement, buildings

What is it?

Impervious surface is a measure of land cover. It is derived from the National Land Cover Database using satellite imagery primarily from Landsat. Images are analyzed to reveal 16 land cover classes, including: water, developed, barren, forest, shrubland, herbaceous, planted/cultivated, and wetlands. Each land cover class is assigned a value for percent imperviousness based on a 30*30km resolution raster data set (USGS National Landcover Database). It is important to note that the percent impervious surface measurement is an estimate of imperviousness and not a direct measurement.

This indicator covers a process category and serves as a potential measure of impact of development on water quality and geomorphic processes.

Why is it Important?

Impervious cover is a relatively easily measured metric that is valuable for watershed planners, storm water engineers, water quality regulators, economists, and stream ecologists (Schueler et al. 2009). It also acts as a measure of development and growth. Direct impacts of impervious surface include changes in land cover, hydrology, geomorphology, and water quality. Indirectly, impervious surface impacts stream ecology, species richness, the economy, policy, and social well-being and human health. Bellucci(2007) cites multiple papers documenting the influence of land cover change on stream health, biotic integrity, and runoff; stating that increases in urbanization results in stormwater runoff that contributes to "flashier hydrograph, elevated concentrations of pollutants transported from impervious surfaces to streams, altered channel morphology, and reduced biotic integrity with dominance of more tolerant species."

What is the target or desired condition?

There are many estimates for a threshold of percent impervious surface, beyond which, measurable damage to stream systems is apparent. Wang et al. (2003) estimate that between 6-11% impervious area, major changes in stream fish populations could occur. Fitzgerald et al. (2012) estimate increased sensitivity of stream ecosystems at between 5-10% impervious surface. Hilderbrand et al. (2010) suggest that within their study area, once percent impervious area reaches 15% a loss of nearly 60% of benthic macroinvertebrate taxa could occur. Schiff et al. (2007) calculate that above a critical level of 5% impervious surface, stream health declines. However, Allan (2004) makes the argument that although there is strong influence on stream health and land cover change, direct associations are complex and depend on anthropogenic and natural gradients, scale, nonlinear responses, and the difficulty in parsing out impacts from today and the past.

Thus, modeled predictions that utilize actual monitoring data for regions of interest, the stream indicators of greatest concern, the main land cover type , and represent a range of possible outcomes may be more realistic (Schueler et al. 2009). Furthermore, Schueler et al. (2009) mention several caveats regarding the use of impervious surface as an indicator for stream hydrology and health. These caveats include: consideration of watershed scale, problems with forming relationships between impervious surface and watersheds with major point source pollutant discharge or dams, importance in grouping watersheds within the same physiographic regions, and caution when applying models based on impervious surface when management practices are poor, especially in areas of low impervious cover (Schueler et al. 2009).

Target conditions were based on the non-linear relationship between watershed impervious area and stream condition (Figure 10). For geomorphic processes, a mathematical relationship was used (Equation 1) that was derived from field studies of effects of total impervious area (TIA, as %) effects on stream geomorphology (Fitzgerald et al. 2012).

$$\textit{Equation 1: Geomorphic Condition} = 0.197 - 0.15 \ln TIA^{*}$$

For water quality, an adaptation of a relationship developed by Schiff and Benoit (2007) was used (Equation 2)

$$\textit{Equation 2}: \textit{Water Quality Index} = a + b \times \exp(c \times TIAWatershed\,\%)$$

Where a=asymptote, b=scale, c=growth rate. For the current analysis, a = 2.59, b = 6.50, and c = -0.17, respectively. The scales for both scores are already normalized between 0-1, so the condition score * 100 was used as the Geomorphic Condition (GC) and Water Quality Index

(WQI) scores for each sub-watershed (see Technical Information section 2.2.9 for more information).

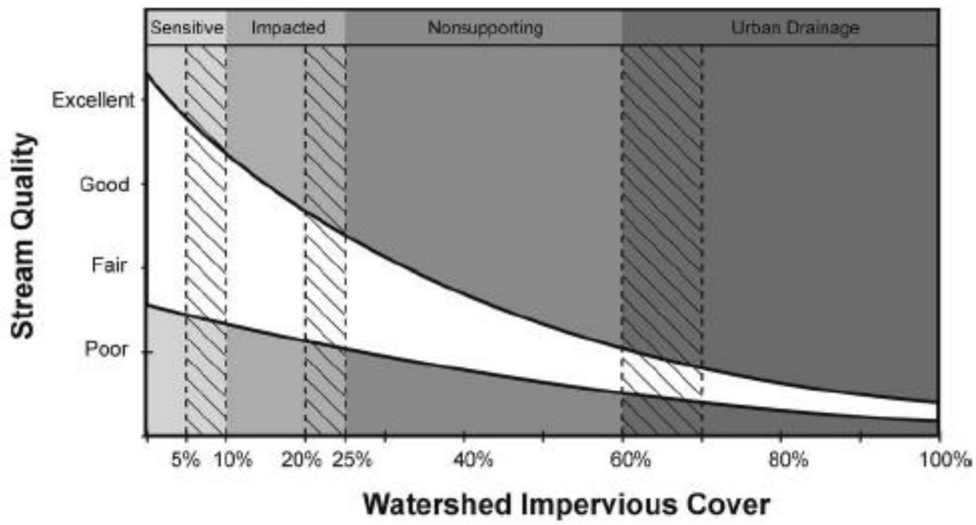

Figure 10. Conceptual model of impervious surface. This illustrates a range in stream quality as a result of impervious cover and the wide variability in stream indicator scores for impervious surface cover below 10% (Schueler et al. 2009).

What can influence or stress condition?

This indicator has a direct connection between stress and percent impervious surface. Therefore, development or conversion of land from "natural" to agricultural land or urbanized land is the only thing that could alter this condition. Furthermore, as stated previously, changes in land cover can indirectly affect geomorphology, water quality, and ecosystem health in terms of native species richness.

Climate change may influence the resulting scores (GC, WQI, etc.) from this indicator by altering the timing and amount of precipitation as well as drought. Climate predictions result from a combination of scenarios and climate models that integrate estimates of greenhouse gas emissions and how the climate system will respond to these emissions. Therefore, variation within the predictions may result in different policy implications and actions. Furthermore, we are likely to see variation in the location, amount, and timing of precipitation rather than homogenous responses across the globe.

Basis of calculation and use

For the purposes of our analyses, we used impervious surface spatial data from the years 2001 and 2006. Spatial data for 1992 exists, but represents land cover classes, not impervious surface classifications. Methods exist for assigning impervious surface values for these land cover classes, but are location and scale dependent (e.g. Sacramento, San Diego river) and differ in accuracy (McMahon 2007).

One area of interest in the impervious surface indicator is the degree and pace of change over time. Currently data for percent impervious surface is available for 2001 and 2006, with the following important note for comparison between years from the NLCD website: "NLCD2001 Version 2.0 products must be used in any comparison of NLCD2001 and NLCD2006 data products." Furthermore, with regards to analysis using land cover and estimates in impervious surfaces, McMahon (2007) states the importance of resolution in data for informing land cover classes and developing models for impervious surfaces.

What did we find out/How are we doing?

The Santa Ana River Watershed contains 113 watersheds classified with Hydrologic Unit Code 12. Out of these watersheds, the mean impervious area is 12.4 percent (see Figure 14, Table 11), with mean percent of watersheds ranging from 0.03-57.23 percent impervious area. The mean score for the GC is 74 (see Figure 11) with mean GC scores for HUC-12 watersheds ranging from 33 to 100. This is similar to the mean score and range of the WQI scores, with a mean and range of 63 (see Figure 12) and 29-100 respectively (Table 11). All means are based on percent imperviousness per raster grid-cell, ranging from 0-100 percent imperviousness.

The statistical summary for the SAWPA area differs than that completed for the entire state of California under the same criteria. Most notably, the SAWPA area has a higher average impervious area (9.80% higher), a lower GC score (20% lower), and a lower WQI score (27% lower). These differences are evident on Figure 13, where the dark red area encompassing the SAWPA area represents higher mean impervious area than most of the state.

Table 11. Summary statistics for mean impervious area, GC scores, and WQI.

	SAWPA Mean Percent Impervious	Difference from state value	SAWPA GC score	Difference from state value (%)	SAWPA WQI score	Difference from state value (%)
Mean	12.4	9.80	74	-20	63	-27
Standard Error	1.46	1.35	2	2	3	2
Standard Deviation	15.60	7.43	24	10	29	10
Range	57.20	-11.56	67	-3	71	0*
Minimum	0.03	0.03	33	3	29	0*
Maximum	57.23	-11.53	100	0	100	0

Values averaged among all watersheds with HUC 12 classification). Negative values indicate decreases in values while positive numbers indicate increases in values. *=not exactly zero.

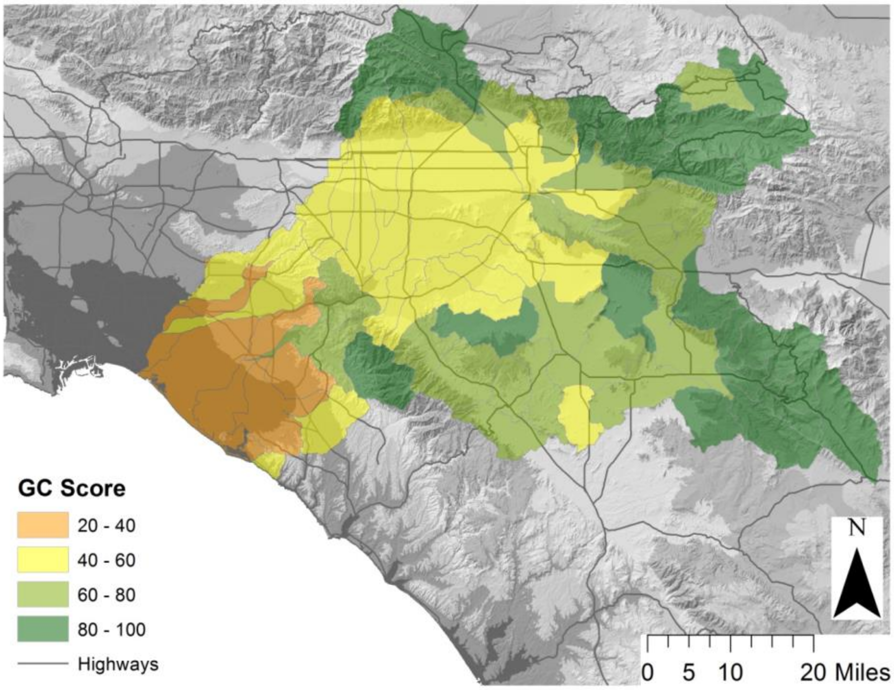

Figure 11. The geomorphic condition (GC) scores for each "HUC12" sub-watershed within the SAWPA service area.

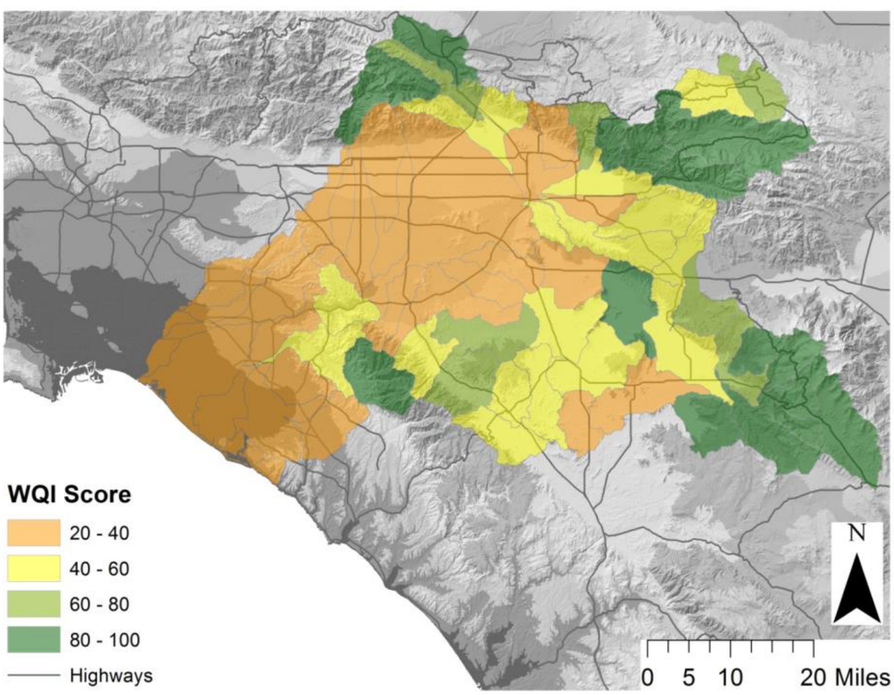

Figure 12. The Water Quality Index (WQI) scores for each "HUC12" sub-watershed within the SAWPA service area.

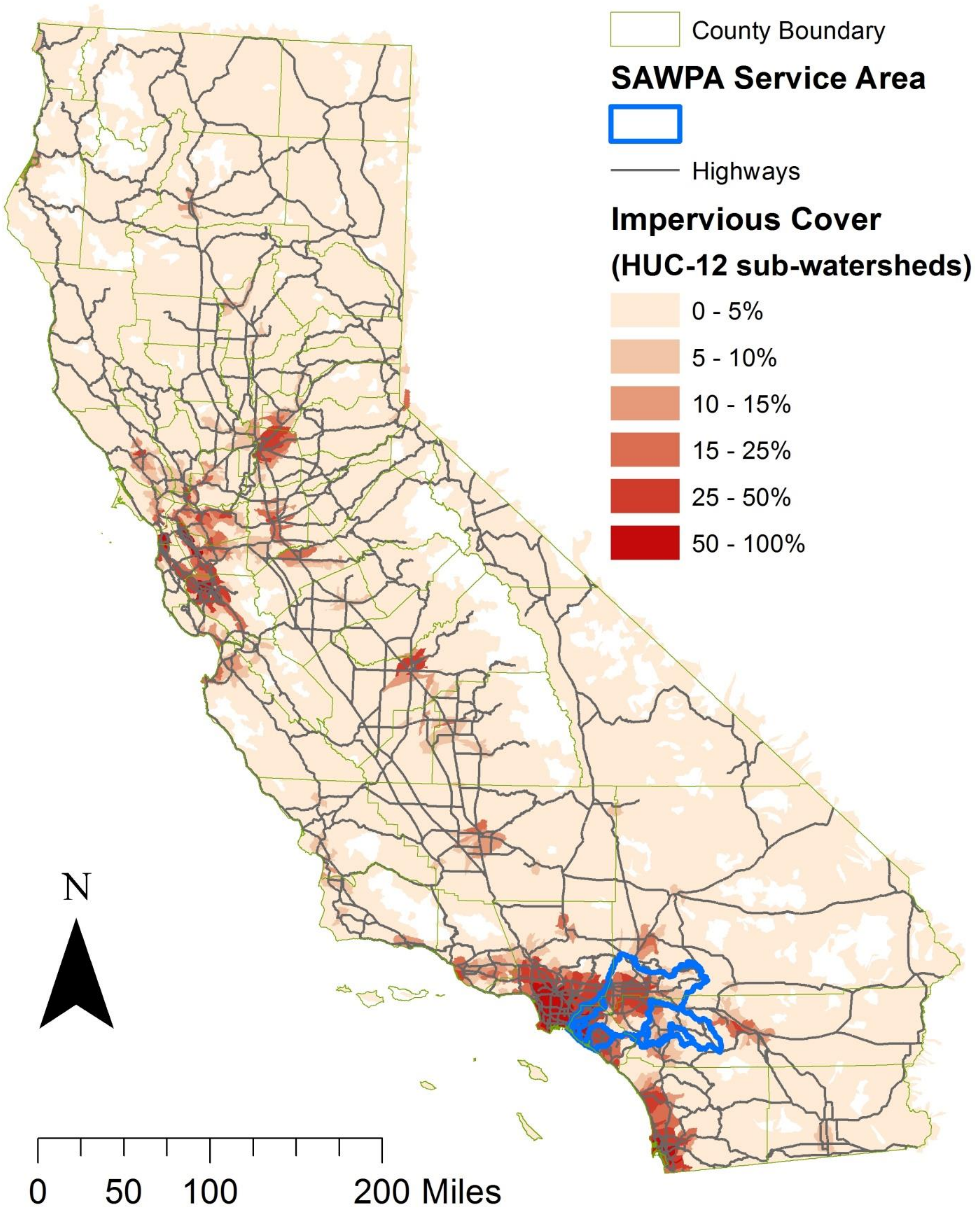

Figure 13. Mean percent impervious cover for the state of California with the Santa Ana Watershed Project Authority region outlined in blue.

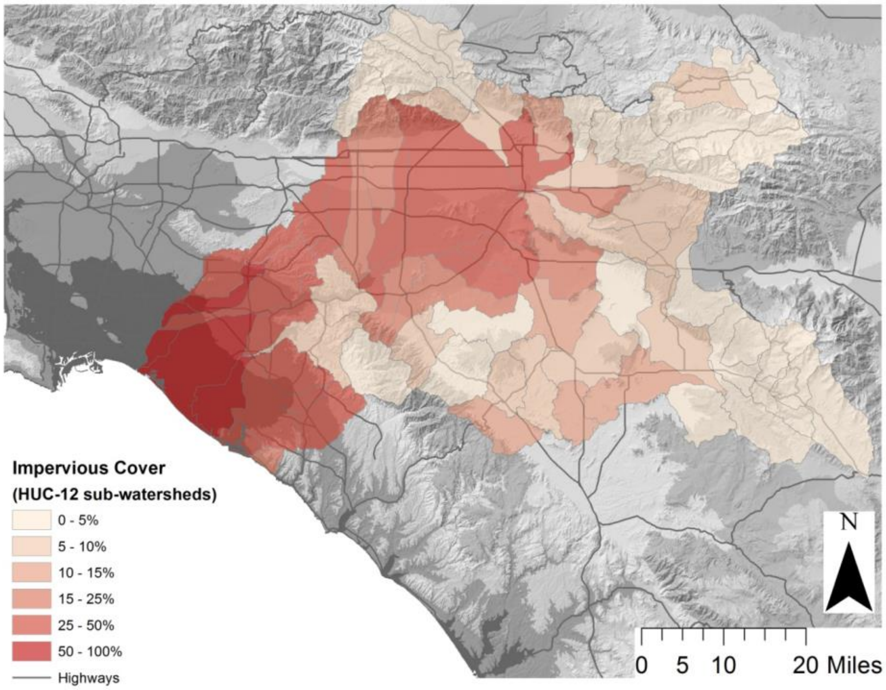

Figure 14. Mean percent impervious cover for each "HUC12" sub-watershed within the SAWPA service area.

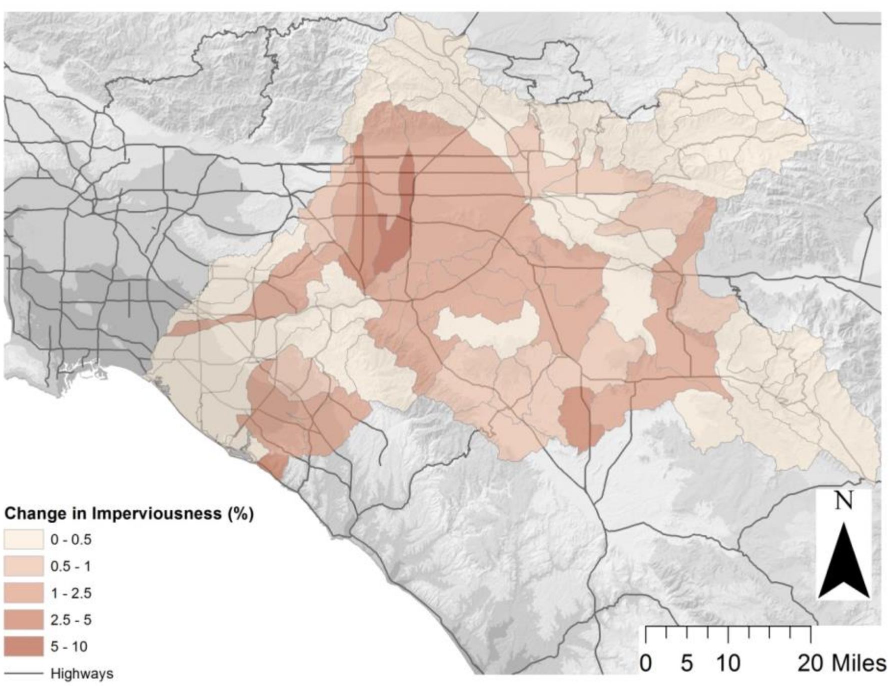

Figure 15. The change in mean percent impervious cover between the years 2001 and 2006 for each "HUC12" sub-watershed within the SAWPA service area

Table 12. Summary change in mean percent impervious area for the Santa Ana River Watershed

	Change in Mean Percent Impervious Area
Mean	0.59
Standard Error	0.10
Median/Mode	0.09/0
Standard Deviation	1.05
Range	7.51
Minimum	0
Maximum	7.51

Although the analysis of impervious area in the Santa Ana Watershed reveals subwatersheds with high percent impervious area, there is still room for improvement from policy and planning efforts. The areas with lowest degrees of change from 2001-2006 are the least (mountains) and most (cities) densely-populated places. Because change in impervious area is measured as an increase in impervious area only, either due to new development or higher imperviousness, areas with already high imperviousness have less potential for growth. Therefore, areas that are surrounded by high percent change in imperviousness may represent areas where urbanization is encroaching. Depending on the ecosystem value of this land, these areas might represent priority areas for action with regards to impacts of impervious surfaces to water quality and geomorphology.

Geomorphic Condition and Water Quality Index Scores

Both these indices reveal higher negative impacts from impervious surfaces near area of high development. The upper reaches of the Santa Ana River score higher on both indices because of the lack of impervious surface development.

In addition to direct impacts of impervious surfaces on water quality, the direction of flow may aid in better water quality measurements. Rivers in this watershed flow east to west and down in elevation from the San Bernardino Mountains to the Pacific Ocean and pick up pollutants as they flow through agricultural or urbanized areas. The Southern California Association of Governments (SCAG) reports that water quality is primarily affected by salinity, chlorides, nutrients, pathogens, and total dissolved solids.

Temporal and spatial resolution

Although percent impervious surface can be conglomerated or displayed at the state level, it is more informative at smaller spatial scales that are appropriate to the analysis at hand. This is because the response of water quality, hydrology, and biotic condition to impervious surface will depend on the location and the scale of measurement. For example, when looking at fish richness, grouping physiographic regions or ecoregions based on species habitat requirements is more informative in developing predictive models than when examining the entire state of California with all its diverse aquatic habitats. Other considerations might include particular habitats, topographies, climates, and even degrees of development, both urban and agricultural.

Knowledge of local scales is also vital when percent impervious surface is simply used as an indicator to track speed and direction of development. For example, Figure 15 reveals that without knowledge of the current state of impervious surface in the Sacramento and Los Angeles regions, one might assume that the percent change reflects a higher degree of concern with regards to impervious surface in the Sacramento region, when in reality Los Angeles does not signal large changes in impervious surface simply because it is already mostly developed. The Los Angeles region may, in fact, require more conservation action to protect or reverse negative impacts of impervious surface than the Sacramento region, while the Sacramento region still has some land not yet impacted by imperviousness, but could be managed to prevent many negative side effects. Therefore, it is important to remember that the state-wide analysis is best used as a starting point from which local analysis and policy decisions can be made.

How sure are we about our findings (Things to keep in mind)

The NLCD analysis is not perfect. Interpretations in land cover based on satellite imagery and subsequent applications of models to determine the percent impervious cover for the years 2001 and 2006 may not be wholly precise, but serve as a good estimate of impervious surface throughout the United States.

Also, our analysis relies on the zonal statistics function in ArcMap, which averages the raster values for percent impervious surface throughout the entire watershed. This removes the ability to detect smaller, spatial changes in additions or increases in percent impervious surfaces. Thus, calculations made on GC and WQI from these statistics are not perfect, but represent a starting point from which more detailed analysis on smaller spatial scales can begin.

We did calculate confidence intervals on the mean percent imperviousness in each sub-watershed, so some degree of understanding about our confidence in the calculations based on these values can be assessed. For example, Figure 16 illustrates the frequency of 95% confidence intervals for all the watersheds. It is clear from this figure that most watersheds exhibit small confidence intervals based on their calculated means, thus our analysis can be said to be fairly precise.

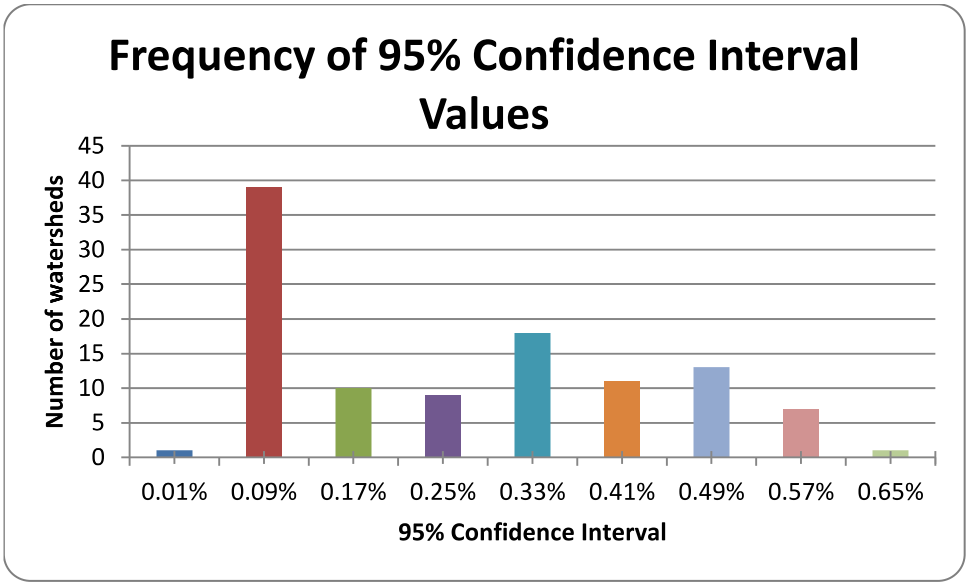

Figure 16. Frequency of 95% confidence intervals that explain up to 96.5% percent of the data.

This is possible, because although there is also a high degree of standard deviation, representing those watersheds that contain raster cells that have a very high range in values, the resulting mean calculated for each subwatershed is based on a very high number of individual raster cells (n=17,093 to 457,193). This resulted in a fairly confident estimation of the mean impervious area within each subwatershed.

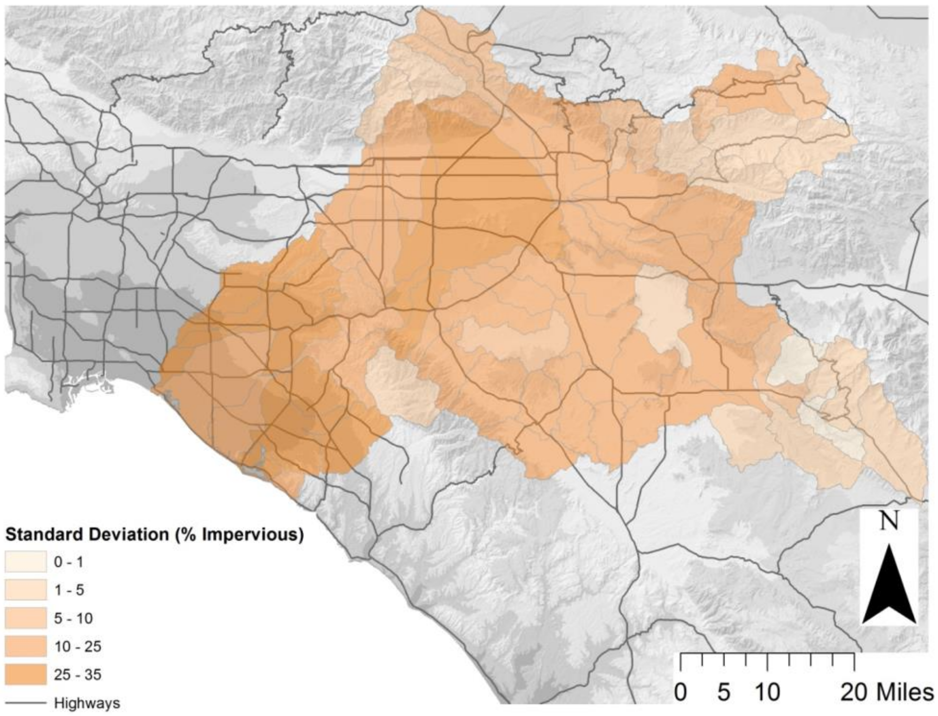

Figure 17. The standard deviation in means for percent impervious area within each HUC 12 subwatershed. Darker shades represent higher standard deviations.

These uncertainties serve as another example as to why it is important to have a good understanding of the study region of interest, and how data such as this can be best used to inform decisions on land use, water management, and ecological conservation.

Technical Information

Data Sources

Spatial data for the impervious surface analysis come from:

3) United States Geological Survey
    a) National Land Cover Database
        i) Spatial data for years 2001 and 2006
        ii) Change in percent imperviousness
        iii) Percent Imperviousness

Data Transformations and Analysis

Data were downloaded from the NLCD database in zip files that included raster files for import into ArcGIS. We used Arc GIS spatial software to display percent impervious surface throughout California. To illustrate effects on individual watersheds we used Hydrologic Unit Codes representing the smallest sub-watershed level (HUC 12). Zonal statistics within each sub-watershed resulted in means and standard deviation from which confidence intervals at 95% were calculated. To illustrate change in percent impervious surface, zonal statistics were performed on spatial data for the change of impervious surface between the years 2001 and 2006. Because of challenges in comparing NLCD datasets from these two years, we used spatial data calculated by Fry et al. (2011) and Xian et al. (2011) for our analysis.

Relationships between percent impervious surface and geomorphology, water quality, and species richness can provide guidance in urban planning, water management, and conservation of natural ecosystems and related species. Here, we suggest four potential indices that could be informed by the impervious surface indicator.

Rapid geomorphic assessment

The rapid geomorphic assessment is a measurement of the geomorphology of a watershed based on the channel and floodplain geometry and planform, bed substrate, bank erosion, and bank and buffer vegetation. A composite calculation for GC was developed using four "adjustment processes" assigned 20 points each, are summed, and then normalized to develop a score ranging from 0 to 1. These "adjustment processes" are: Channel degradation, Channel aggradation, Channel widening, and Change in planform. A line was fit to the normalized GC scores associated with the total percent impervious area using a stepwise regression analysis and the addition of "other natural watershed characteristics" for high-gradient and low-gradient study reaches (Fitzgerald et al. 2012). The line for the high-gradient reach represents the model used in our analysis (see Figure 18 and Equation 1).

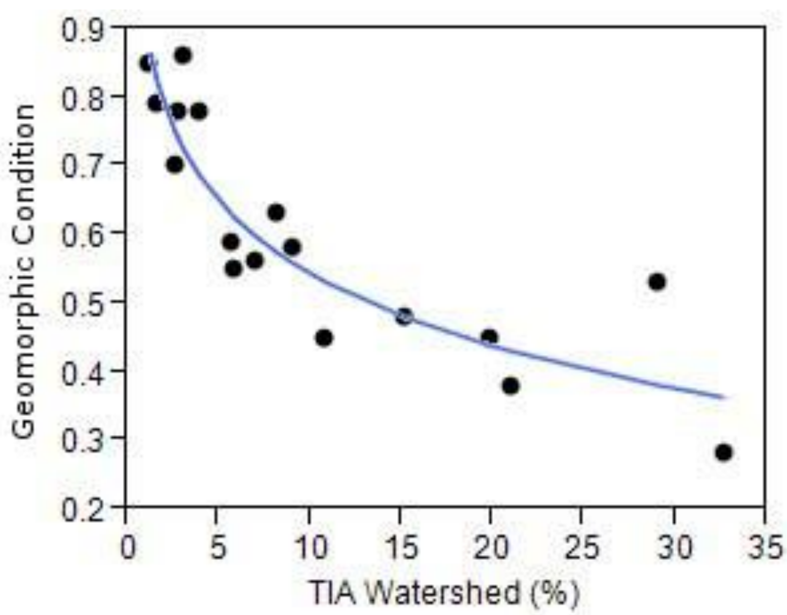

Figure 18. Plot of the Relationship Between GC and percent total impervious area (TIA). Adapted from Fitzgerald et al (2012).

$$\textit{Equation 1: } GC = 0.197 - 0.15 \log TIA^{*}$$

*The equation should be interpreted as natural log (ln) of Total Impervious Area (TIA).

Because the scale is already normalized between 0-1, we used the raw GC calculation in our depiction of GC for each sub-watershed.

Water Quality Index

The water quality index (WQI) is a measure of water quality based on seven aspects of water chemistry: Total dissolved solids, suspended particle matter, fecal coliform, nitrate, phosphate, the chloride to sulfate ratio, and the nitrate to total nitrogen ratio. Schiff and Benoit (2007) use these seven parameters to calculate water quality using the following formula:

$$WQI = 10 - \left(\frac{10}{7}\right) \times \sum_{i=1}^{n} \left(\frac{P_i}{P_{imax}}\right)$$

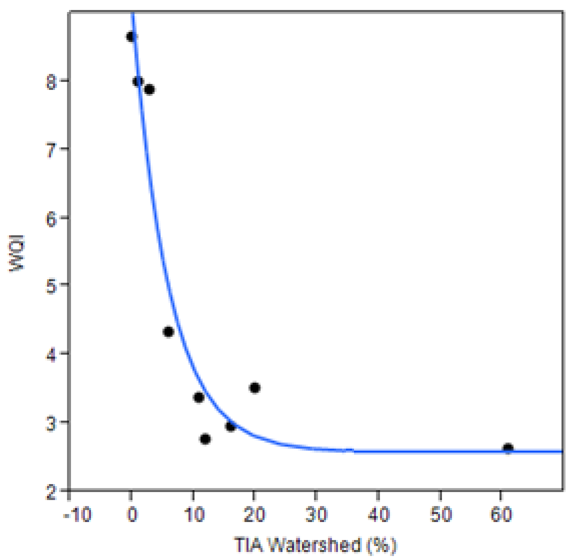

Figure 19. Water Quality Index (WQI) vs. Total Impervious Area (TIA) at the Watershed Scale. Adapted from (Schiff and Benoit 2007).

Once WQI is calculated a line is fit to the data using an exponential decay transformation (Figure 19). The resulting equation used for our model is:

$$a + b \times \exp(c \times TIAWatershed\ \%)$$

Where a=asymptote, b=scale, c=growth rate. For our analysis, the related values are 2.59, 6.50, and -0.17, respectively.

Relationships between percent impervious surface and the GC and WQI models were calculated by performing a spatial join in ArcMap between the calculated values of GC and WQI and the zonal statistics of percent impervious surface within each HUC 12 sub-watershed. We left the GC scaling intact because the resulting data ranged from 0-1, but altered the WQI scale to a similar scale of 0-1 by dividing the WQI value by 0.85. This resulted in a new scale ranging from 0-1 where 1 represented the highest possible score within the state of California.

Indicator 9: Coastal Impacts from Sea Level Rise

What is it?

Sea level rise is one consequence of continued climate change. The sea has already risen by up to 8 inches along the California coast and is projected to rise another 4 to 5 feet by the year 2100 (Jevrejeva, et al., 2010; Rahmstorf, 2007; Pfeffer et al., 2008). This indicator consists of 4 primary metrics: 1) extent of potential economic damage from inundation; 2) number of people affected by inundation; and 3) extent of natural system damage from inundation. Coastal impacts of sea level rise could reach >$200 billion and displace hundreds of millions of people by 2100 if mitigation and adaptation actions are not taken (Hinkel et al., 2013).

Why is it Important?

Because sea level rise and its impacts won't occur all at once, there will be both a gradual rise in sea level elevation and time to begin adaptive action, when and where that is possible. Inundation by sea water is one way that sea level rise can impact human and natural systems. Although this is thought of primarily as a coastal effect, inland waterways and estuaries, storm-water systems, wastewater treatment, and groundwater/aquifers can all be impacted by sea level rise.

As coastal beaches and marshes are impacted and degraded by sea level rise, they will lose their functions as habitat and as a buffer to wave-action for human infrastructure. California coastal marshes, tide-flats, beaches, dunes, and other environments are habitats at-risk and home to many listed plant and animal species. Degradation and loss of these habitats will push some species toward extinction unless the habitats can adapt to higher sea levels by accreting more material. Natural coastal features protect many roads and buildings from wave action and other effects of storms. If they are lost, there is a greater chance that structures will be impacted and communities will incur costs to protect or replace them.

What is the target or desired condition?

There are two types of relevant desired conditions: 1) limited impact to coastal systems (artificial and natural) from sea level rise because of limitations on greenhouse gas emissions and 2) resilience or adaptation by systems exposed to sea level rise. In the first case, the desired condition is for sea level to rise no more than it already has in response to climate change (~8 inches along CA coast; Flick 2003). The corresponding undesired condition is for sea level to rise at the maximum predicted rate due to climate change. In the second case, the desired condition is for natural and artificial systems to adaptively change in response to sea level rise so that impacts are minimized. For this to be sustainable change, the human adaptive activities would not negatively impact natural systems and ideally would benefit adaptation by these systems. The corresponding undesired condition would be for adaptive responses to be non-existent or maladaptive to natural or human systems.

What can influence or stress condition?

Climate change is likely to bring both sea level rise and increased wave action and storminess. Climate change is primarily caused and exacerbated by greenhouse gas emissions (GHG). Its effects can be ameliorated or exacerbated by solar cycles, particle and aerosol emissions into the atmosphere, and feedback cycles (e.g., warming-caused increases in carbon dioxide and methane emissions). If human releases of GHGs were immediately curtailed, it is possible that global mean temperature rise could be limited to ~2oC above pre-industrial mean. This would still mean a further rise in sea level, because of existing momentum in the various atmospheric, marine, and terrestrial systems (Wigley, 2005).

It is possible that coastal communities and states will be able to build appropriately adaptive systems that reduce the impact of sea level rise on both human and natural structures and processes. It is also possible that inappropriate structures will be built and actions will be taken that will exacerbate, or fail to deal with these impacts. For example, sea walls adjoining beaches may temporarily protect houses, but they may also eventually fail because of the erosion of protective beaches and displace effects onto adjoining natural and human structures.

Basis of calculation and use

For the purposes of our analyses, a simple overlay of potential sea level rise and sea incursion inland was used to estimate the extent and types of impacts. The indicator is proposed as looking forward, therefore no assessment of existing condition was carried out.

What did we find out/How are we doing?

Over half of the length of the coastal areas of the Santa Ana River Watershed will potentially be impacted by sea level rise. Only parts of Huntington Beach are likely to not face some level of inundation with sea level rise of 1.5 meter. Along the remainder of the Santa Ana watershed coastline, 27 schools, 2 fire stations, one police station, one hospital, and one wastewater treatment plant is vulnerable to a 1.5 meter rise in sea level.

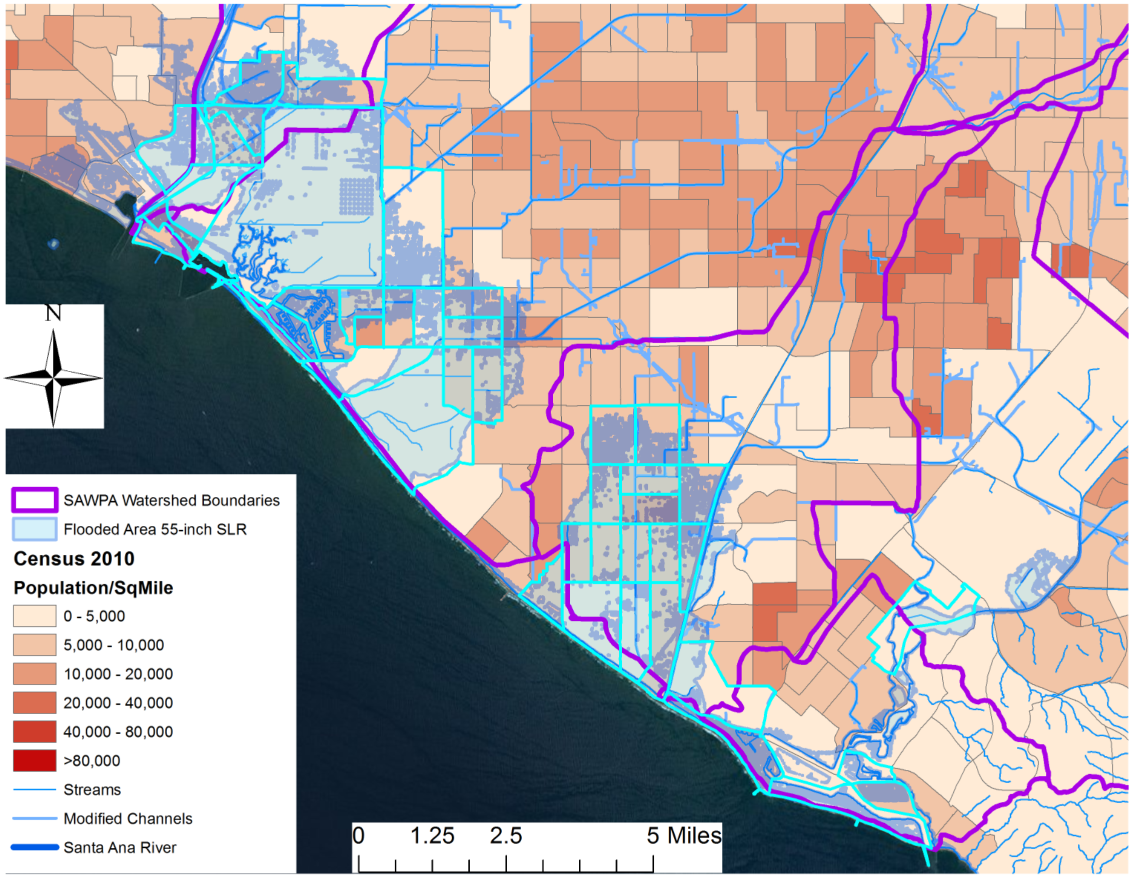

Figure 20. Potentially-inundated populated areas due to sea level rise of 1.5 m (blue areas, projected by 2100) overlaid onto Census 2010 blocks, color-coded for population density.

There are about 6 million people living in the SAWPA service area, by 2050 there may be 10 million people. Assuming current population densities, approximately 163,940 people (2.7% of the population) and 76,340 housing units are in census tracts where at least half of the tract is covered by a projected SLR of 1.5 m. This does not mean that all of these housing units would be affected, but rather that there is the potential for a significant impact to people and properties in coastal areas from sea level rise. Assuming a fairly conservative median house price for Orange County of $500,000/unit., a very rough estimate of lost property value due to sea level rise of 1.5 m is 76,340 units times $500,000/unit = $38.2 billion. This number dwarfs the size of the carbon-trading market in California, estimated to be ~$2.3 billion and is almost half the size of the global carbon-trading market. However, both of these markets are likely to grow during the time the 1.5 .m sea level rise is expected to occur.

The point of this assessment is that prices of properties potentially affected by SLR along the South Coast are well above the range of values of the market tools, suggesting that either the marketed is under-valued, or is not likely to be effective.

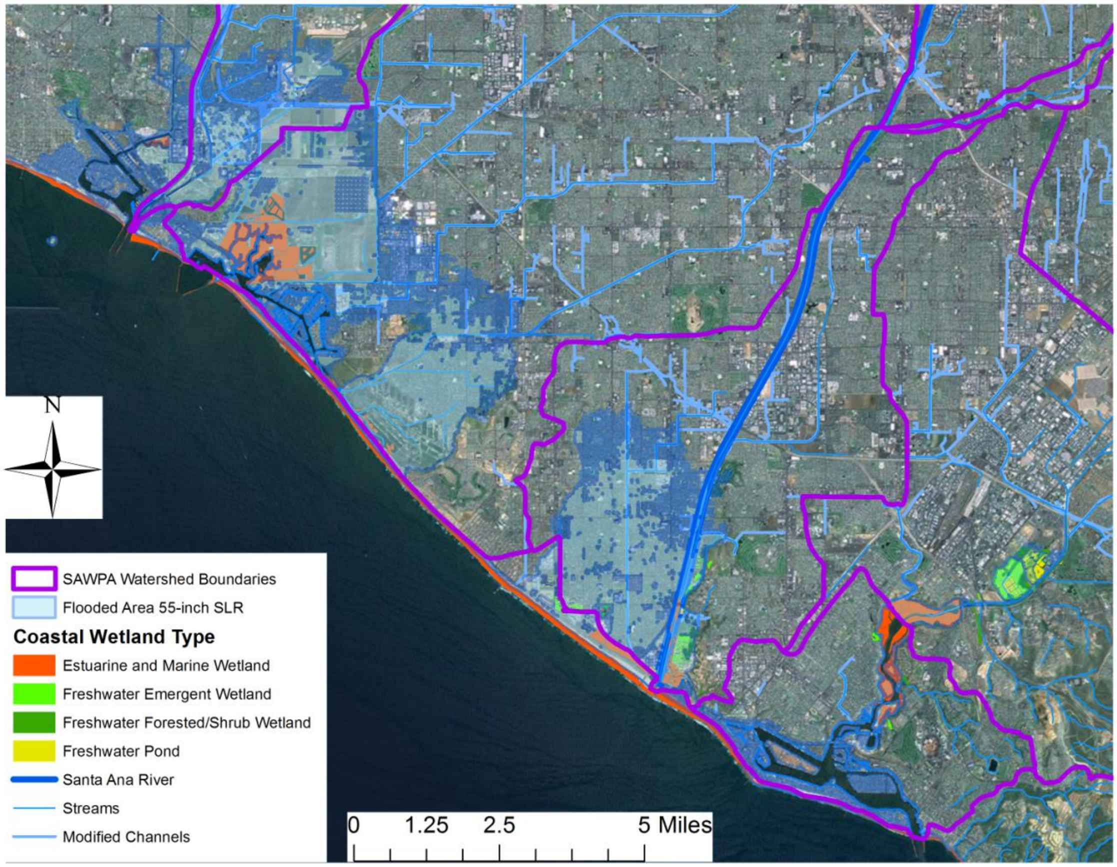

Figure 21. Potentially-inundated wetland areas due to sea level rise of 1.5 m (projected by 2100).

A projected rise of 1.5 m sea level rise will lead to ~660 Ha of coastal and estuarine wetlands being inundated, representing about 99% of these wetlands in the SAWPA area. This assumes no negative (e.g., erosion) or positive (gain in wetland relative elevation) response by the wetlands. The ability of wetlands to adapt to sea level rise remains an active area of research.

Temporal and spatial resolution

The potentially-inundated areas are for the year 2100. Prior to that there are likely to be more gradual impacts from sea level rise and it is likely that populated areas will either become less-populated, or coastal armoring will be attempted. Without monitoring of actual changes in impacts, most evaluations are modeled. Finer temporal resolution and nearer-term evaluations of sea level rise and impacts might be useful for coastal planning. The temporal resolution of marsh/wetland impacts is hard to predict because marsh adaptation is relatively unknown. The spatial resolution of potential impacts is likely accurate for wetlands because there are not retreat areas available for these wetlands. The spatial resolution of impacted areas in populated areas is unknown because response actions are hard to predict.

How sure are we about our findings (Things to keep in mind)

The potentially-inundated populated and wetland areas are modeled areas in a mapping environment. There is no way to know how accurate these predictions are without shorter term monitoring and modeling to track sea level rise and its geomorphic impacts on the coastline.

Technical Information

Data Sources

The Impacts of Sea-Level Rise on the California Coast
http://www.pacinst.org/reports/sea_level_rise/index.htm

Indicator 10: Aquatic Habitat Fragmentation

What is it?

Aquatic fragmentation is the potential hydrologic alteration caused by diverse type of structures, such as dams, weirs, drop structures, and other man-made systems that modify hydrologic flow.

It is an Influence indicator that is directly or indirectly connected to effects on aquatic habitat functioning and species condition. It also represents the impact of development and/or land use in the watershed. The effects of structures are not limited to roads. Other disturbance features, such as seismic lines, pipelines, and rail lines, have been shown to have both direct (increased mortality) and indirect (avoidance of high quality habitat) effects.

The Aquatic Fragmentation Indicator identifies the proportion of the watershed or stream segments unfragmented by dams and low-level crossings. A complementary metric proposed in this assessment is the density of road/stream intersections within a watershed area.

Why is it Important?

Streams and rivers may be disconnected by physical and other barriers. Dams, culverts, in-stream impoundments, high temperature, and excessive aquatic plant growth can all separate waterways into segments (Bourne et al 2011). Fragmentation caused by these natural or artificial barriers cause different effects in watershed health and wildlife that depend on it.

Changes in physical, geomorphological and chemical properties of watersheds are one type of aquatic fragmentation impacts. Natural processes are also altered by the physical and structural changes in watershed and consequently, aquatic organisms and their life cycles are also impacted. Locations where roads cross waterways change the natural shape of the river and how it is allowed to flow through the barrier. This can increase sediment transport and deposition and erosion in riparian habitats (Warren and Pardew 1998, Forman and Alexander 1998). Increases in sedimentation lead to changes in flow regime and water stability, stream channel instability, and reduced water quality (Rieman and McIntyre 1993). An increase in fine sediments, particularly in small spawning streams, can have negative impacts on fish egg survival and spawning success and may directly kill aquatic organisms (Newcombe and Jensen 1996).

Aquatic fragmentation has direct and indirect effects on the ecology, diversity and abundance of a variety of aquatic organisms. Andrew and Wulder (2011), for instance, analyzed the relationships between the population trends of Pacific salmon, from 1953 to 2006, and land cover, fragmentation, and forest age. Their results showed that effects are species specific, but characteristics indicating a legacy of historic and current forest management generally had negative effects, driven by a small subset of highly fragmented watersheds. In particular, the results showed that chumandcohosalmonhadstrongnegativerelationshipswithfragmentation. Bain and Wine (2010) studied watersheds in the Hudson River and found out that large stream fragments support higher species diversity, more abundant populations, and a greater range of fish sizes.

In addition, the movement and migration of aquatic species is altered due to aquatic fragmentation. Crossings and higher barrier frequency could be associated with increases in the water velocity due to the configuration of a road crossing and are inversely proportional to fish movement (Warren and Pardew 1998). Raymond (1979) and Fergusson et al (2006) have documented that turbines and dams have adverse effects on survival and migration of juvenile salmon, mainly chinook and steelhead, in the Columbia River system.

Roads can also increase the risk of overharvesting for many game fish species (i.e. lake trout and bull trout); for example, road densities as low as $0.1 km/km^2$ have been found to negatively influence trout populations, and new road access into previously remote aquatic habitats can increase angling and poaching mortalities (BCMWLAP 2002).

In summary, whole watershed connectivity is critical for effective conservation of rivers and networks of wetlands to ensure natural processes (Moilanen et al. 2009; Nel et al. 2009); including upstream connectivity, maintenance of biological diversity, fish migratory routes, free-flowing rivers, significant water yield areas and water quality.

What is the target or desired condition?

The desired condition, from an ecological health standpoint, is that waterways in local, regional and statewide scales have a minimum or no fragmentation, so they can conserve or resemble the historical natural watershed connectivity that will allow aquatic species and systems to function correctly. The target condition is to get a score of 100 for each watershed area evaluated, which means that the 100% of the watershed is unfragmented and the density of road/stream intersections is 0.

What can influence or stress condition?

The desired condition of an unfragmented watershed system can be influenced by any type of structure or barrier that disconnect or limit the natural flow of the waterway and will affect directly or indirectly its biological and physical features. Large and small barriers should be considered when evaluating riparian conservation efforts considering that both types of structures have effects on wildlife (Tiemann et al 2004) in the watershed.

Basis of calculation and use

The scoring system for aquatic fragmentation comes from two distinct methods. The first involves a percentage of the HUC 12 (2012) watershed that is “unfragmented”, that is, above a disturbance site. In this analysis, we use the Passage Assessment Data (PAD) (2013) data to demarcate new watersheds we refer to here as “PAD watersheds”. All watersheds created by the PAD data points represent areas of the HUC 12 that is separated from the rest of the HUC 12 watershed downstream. In some cases these PAD watersheds are much smaller than the HUC 12 watersheds; in others they are much larger. To account for this variability, we also use an additional measure, the density of road/ stream intersections within each HUC 12 watershed in a standardized per unit length of stream as determined by the National Hydrography Dataset (NHD) (2013). These two methods are combined to create a scoring system by which each HUC 12 watershed within the area of interest is ranked.

What did we find out/How are we doing?

Of the 74 HUC12 polygons in the Santa Ana Watershed, a little over half are approximately 31% fragmented due to road stream intersections. No watersheds surpass 50% fragmentation, and 3 watersheds have less than 6.25% fragmentation (Table 13 & Figure 22).

Table 13. Proportion of watersheds (HUC-12) in different % fragmentation classes.

Percent Fragmentation	Number of Watersheds	Cumulative % Watersheds
50.00	1	1.35
43.75	1	0.00
37.50	5	6.76
31.25	16	51.35
25.00	9	22.97
18.75	12	35.14
12.50	20	72.97
6.25	7	13.51

<6.25	3	2.70

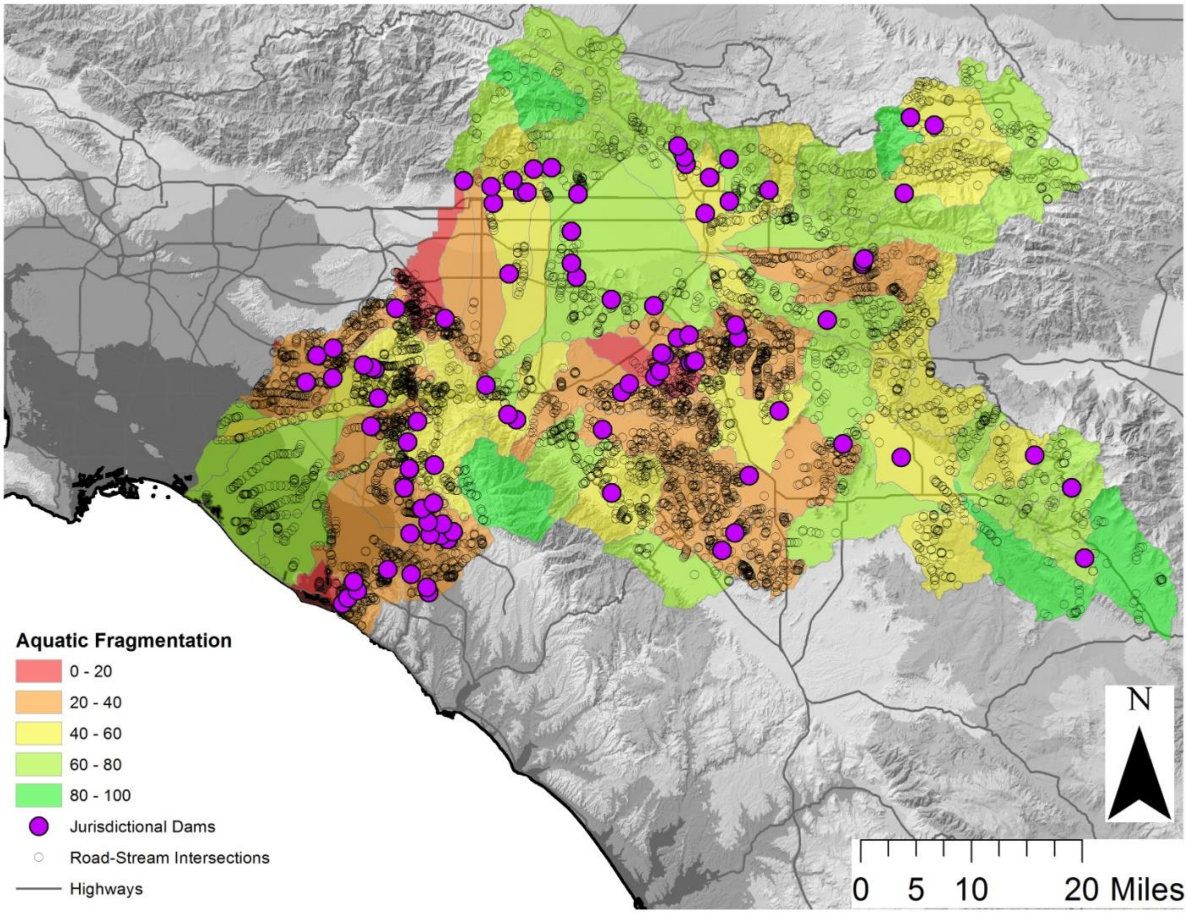

Figure 22. Aquatic fragmentation elements (dams and roads) and corresponding score for each HUC-12 in the SAWPA area.

How sure are we about our findings (Things to keep in mind)

We used the Passage Assessment Database for dam location in the Santa Ana River Watershed. To do this, some manual editing of spatial data was needed. First, we deleted points that did not represent artificial boundaries to aquatic life, and points that were not identified as dams per the NHD metadata. Second, we used aerial footage (Google Earth and ESRI) of the area surrounding PAD dam data points to delete or move the location of PAD points. Because of this, there is likely some uncertainty regarding the placement of data points, and thus the resulting watersheds created using PAD points as pour points in our watershed model.

Technical Information

Data Sources

- Fish Passage Assembly Data (PAD)
- Digital Elevation Data
- CalTrans
- Forest Service
- NHD Data

Data Transformations and Analysis

Dammed watersheds

To determine the boundaries of watershed determined by dams identified in the PAD, we used digital elevation data (USGS) and calculated flow direction and flow accumulation. Using these two variables combined with the PAD dam locations, we created watersheds that represented theoretical flows to the PAD data points. The PAD-dam watersheds were then combined and converted to a raster file. This file represents the area of fragmented watershed- the area above a disturbance such as a dam or culvert.

We calculated the GIS area of each of the HUC 12 watersheds and the area of the PAD-dam watersheds. Using these areas, we calculated the percent of each HUC 12 watershed that is unfragmented, and the degree of fragmentation resulting from dams. We then assigned a value to each HUC 12 watershed based on this analysis. The final scoring system was developed by following a protocol developed by (Davis and Hanley, 2010) dividing the data into natural breaks and assigning an intensity score from low to high based on these divisions.

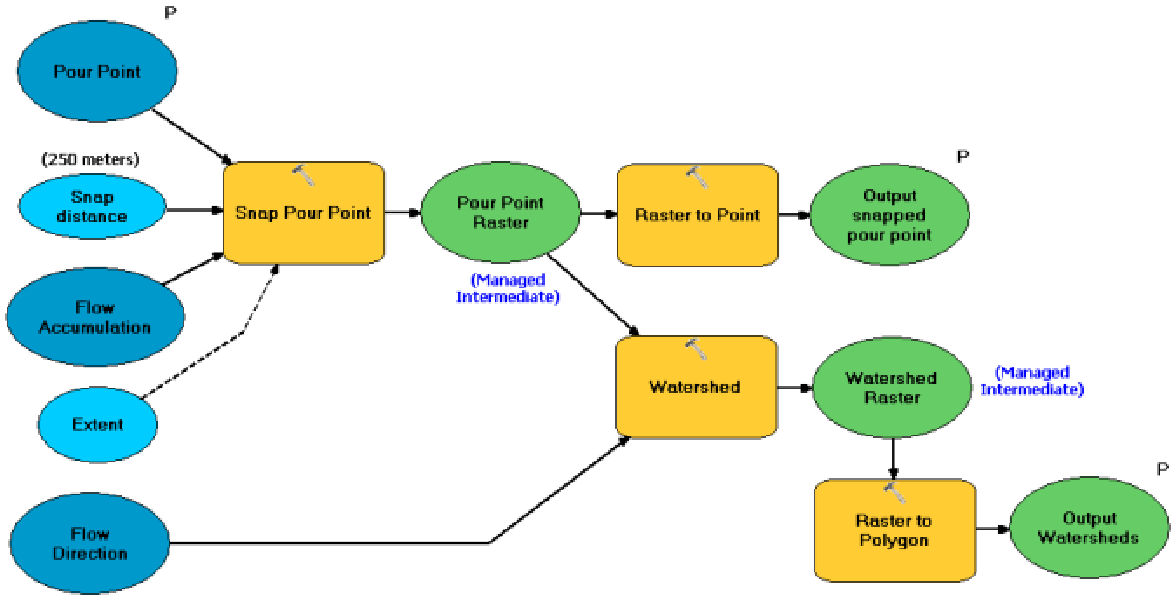

Figure 23. Model for creation of sub watersheds using PAD data.

Density of Road/ Stream Intersections

For this portion of the scoring system, we used spatial stream and river data from the NHD and spatial road data from Caltrans and the Forest Service. We first identified points where roads intersected stream systems and created a layer based on these points. Then, using NHD stream data, we calculated the density of intersecting points per unit length of stream and or river. This value was used to create a map illustrating the percent fragmentation within each HUC 12 watershed due to stream and road intersections.

OWOW Sustainability Goal 1: Preserve and enhance the ecosystem services provided by open space and habitat within the watershed

Indicator 11: Open Space for Recreation

What is it?

This indicator expresses park access within the study watershed. Results are expressed as a percentage of the total population that has ½ mile access to an open space or park.

Measuring park access uncovers the potential for the residents of the watershed to engage with the natural features of the landscape, and speaks to the growing body of literature expressing the value of open space on multiple social outcomes, including obesity and childhood diabetes (Bedimo-Rung, 2005; Reynolds, 2007; Ewing, 2008).

Why is it Important?

Having a sufficient area of accessible open space in the watershed is relevant to many watershed concerns. This indicator measures the accessibility of parks, which speaks to mental and physical health outcomes for the residents due to the greater likelihood of physical activity. Researchers increasingly find links between the attractiveness of the physical environment, on specific criteria, and increased physical activity by residents (Giles-Corti et al., 2005; Reynolds et al., 2007). The assumption in this indicator is that parks within walking distance are indicative of the sort of attractive physical environment that will support increased exercise. Parks are also places of natural habitat, they can provide groundwater recharge benefits, and diminish the urban heat island effect.

What is the target or desired condition?

The ideal condition is for every resident of the watershed to be within ½ mile of a park or publically accessible open space.

What can influence or stress condition?

The distribution of population and recreational open space both influence this indicator. Future assessments could further consider accessibility along demographic lines to judge equity, and could consider public transit networks that increase the accessibility of particular recreational spaces.

Basis of calculation and use

A GIS analysis was performed using 2010 Census tracts and Southern California Association of Governments land-use data for parks and open spaces. A centroid for each census tract was calculated and allocated a value of the total population of that tract. All centroids that were within ½ mile of a publically accessible open space were selected, and the population was summed.

What did we find out/How are we doing?

The Santa Ana River watershed, in this broad measure, provides 70% of the population ½ mile access to open space. Future analyses must consider the equitability of the distribution of who is and is not provided access to open space. Also, a qualitative measure of the fitness of the open space to support the population being directed to it by this analysis should also be included. For instance, a large regional park can usually provide for more than just the proximate population. So too, a small urban pocket park may be overwhelmed by the large population in the ½ mile surrounding it.

Temporal and spatial resolution

The spatial resolution of the data in this analysis is moderate, in that by using census tracts the actual location of residences is not captured. Working at a residential scale is well beyond the scope of a watershed assessment. So too, the park data in this analysis makes some assumptions. For parks, the outer boundary is treated as having no impediments to access, that is, if a park is fenced with only one entrance, the distance to that entrance is not factored here.

In this analysis the distance was "as the crow flies", in that the network of streets and barriers imposed by transportation and utility networks or structures and private property were not included.

Temporally, the 2010 census is as accurate a depiction of the entire watershed population available for analysis, but clearly does not match the current population. The state of infrastructure is less apt to have temporal variation, so parks and barriers are likely very highly resolved.

How sure are we about our findings (Things to keep in mind)

The results of the model can be well-documented and replicated. Using the 2010 census data likely describes the population very well, however future assessments may become less certain as changes in demographics and residential patterns occur.

Using census data to express the spatial location of the population is known to bring uncertainty into an analysis. The area attributed to a census block is unrelated to the actual location inside that space where residences exist. By using the census block as the base area of our analysis, we are making an assumption that at the watershed scale, these inconsistencies will not be predominant in the findings.

This model is designed to express a generalized view of conditions in the watershed. There are many models in the environmental justice literature that probe spatial correlations in access to park accessibility and exposure to locally undesirable land uses. Virtually all confront some of the analytical concerns mentioned here (Liu, 2001; Boone, 2009; Chakraborty, 2009).

Technical Information

Data Sources

The GIS model used in this analysis drew datasets from the following sources:

- Southern California Association of Government – open space and park boundaries
- ESRI stock data - U.S. census shapes and tabular data
- Santa Ana Watershed Project Authority – Santa Ana River Watershed Boundary

Indicator 12: Reduction of Invasive species to maximize health of native landscape

What is it?

This indicator describes how watershed managers are describing and confronting the challenges of invasive species. Both plant and animal invasive species exist in the Santa Ana watershed, and are confronted with management efforts.

Why is it Important?

The presence of invasive species causes degradation of natural processes within the watershed. Native plant species are relied upon for shelter and forage for native animal species. Both invasive plants and animals push out the native species.

What is the target or desired condition?

The target is for invasives species to be well managed. This includes first an assessment of their presence and extent, and then a management response that seeks to remove them. In this case the indicator is framed to first describe the extent to which watershed managers are assessing invasive species, and then to describe how invasives are being removed.

What can influence or stress condition?

Invasive species can encroach into the watershed through a variety of mechanisms. Regional proliferation through natural processes is the most significant, meaning that invasives are extremely hard to eradicate, and therefore need persistent management. Disturbance from fire, development, or flood can also open new landscapes to invading plants. In addition, lack of education can cause people to unknowingly plant or encourage invasives.

Basis of calculation and use

This indicator was not scored. However, an assessment of four invasive plant species was conducted in 2010 by the California Invasive Plant Council. This data depicts the extent of invasives within the Santa Ana watershed at that date. There is no existing clearinghouse of invasive treatment programs, so determining if treatment is keeping up with invasive propagation was impossible.

What did we find out/How are we doing?

Not enough is being done to coordinate invasive species assessment and treatment. The first step must be a clearinghouse of information about existing treatment efforts in the watershed. An update of the Cal-IPC mapping effort of 2010 is needed as well. A program authorized by AB1168 (1999) allows the formation of Weed Management Areas, and the Santa Ana watershed has one listed for Riverside/Orange though activity of the group wasn't easily uncovered.

Indicator 13: Acres covered under restoration projects and conservation agreements

What is it?

This indicator asks if the open space of the watershed is being protected from development that is contrary to the goals of the watershed. Additionally, open space that has previously been degraded through development, pollution or mismanagement can be restored to contribute to desired watershed processes.

Why is it Important?

Protecting open space from development is one important strategy in watershed management. Native habitats, as both themselves a goal but also as an indicator of natural processes, are of import to watershed management in the Santa Ana watershed. Maintaining the areas that remain and improving those that have been degraded.

What is the target or desired condition?

In the Santa Ana watershed, all remaining native habitats should be protected, in some fashion, from development that is contrary to the watershed goals.

What can influence or stress condition?

The pressure of development can overwhelm the goals for the Santa Ana watershed. Using legal protections on land to limit or forbid development is a necessary tool.

Basis of calculation and use

The California Protected Lands Database (provided by Green Info Network), and the Critical Habitat designated lands (where they do not overlap CPLD) were compared to lands designated by SCAG as open space. This provided a ratio of open space land that is under protection of one form or another.

Table 14. Protected Acres in SAWPA Service Area

Description	Area (sq miles)	Percent of Watershed	Percent Protected
California Protected Lands Database	936	32%	100%
Critical Habitat (where not overlapping CPLD)	152	5%	100%
SCAG Open Space (Wildlife preserves and sactuaries, vacant undifferentiated, beaches, undeveloped local parks and recreation, undeveloped regional parks and recreation)	1582	55%	69%
Entire Watershed	2840	100%	38%

What did we find out/How are we doing?

Santa Ana watershed is more than a third open space. Of that, 69% is protected in some way. Most of this is the two National Forests, however there are many other techniques that have come into play. It is important that the remaining open spaces be considered for legal protections that work to align future development with watershed goals.

OWOW Sustainability Goal 4: Protect beneficial uses to ensure high quality water for human and natural communities

Indicator 14: Exceedances of water quality objectives throughout watershed

What is it?

To provide recreational opportunities, the lakes and streams of the watershed must be clean enough to allow safe swimming. For water-based recreation, people must able and legally allowed to access the water. The Santa Ana Basin Plan designates which streams and water bodies have the beneficial uses of REC-1 or REC-2, both of which refer to water-related recreation. Waters designated as Water Contact Recreation (REC-1) beneficial use support recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, white water activities, fishing, or use of natural hot springs. Non-contact water recreation (REC-2) uses of water do not normally involve body contact with water, but ingestion of water is reasonably possible. In most cases, however, stream segments of Southern California have been channelized for flood management, and despite the recreational designation in the Basin Plan, they are made inaccessible by policy and statute.

When streams and lakes are swimmable and fishable, they provide recreational opportunities for people of the watershed. In California, it is the role the Regional Water Quality Control Boards to determine waters that are suitable for these activities and describe Water Quality Objectives (WQOs) to ensure that these waters are protected. In particular, at locations where people are in direct contact with the water, such as swimming and wading, bacterial pathogens should not exceed levels that pose a direct risk to human health. In addition, at locations where anglers are catching and consuming fish, pollutants should not bio-accumulate in fish tissues to levels that are harmful to human health.

Why is it Important?

As defined by regulations, healthy surface water has a long list of beneficial uses. The Santa Ana Basin Plan (SARWQCB, 1995) identifies the following as potential or existing beneficial uses for surface waters in the region:

- Municipal and Domestic Water Supply
- Agricultural Supply
- Industrial Service Supply
- Industrial Process Supply
- Ground Water Recharge
- Navigation
- Hydropower Generation

- Water Contact and Non-Contact Recreation
- Commercial and Sport Fishing
- Warm Freshwater Habitat
- Limited Warm Freshwater Habitat
- Cold Freshwater Habitat
- Preservation of Biological Habitats of Special Significance
- Wildlife Habitat
- Rare, Threatened and Endangered Species
- Spawning, Reproduction, and/or Early Development
- Marine Habitat
- Shellfish Harvesting
- Estuarine Habitat

Water quality monitoring programs typically employ a multiple lines of evidence approach to determine if surface waters are supporting their beneficial uses. These include monitoring a variety of indicators such as chemical and physical constituents, the occurrence of toxic endpoints, riparian habitat, benthic macroinvertebrates, fish, birds, amphibians, and algae. Since chemical and physical constituents respond rapidly

to pollutant inputs and can be quantified and compared to numeric protective values, they are widely used to determine the incidence and extent of water quality impairments. Monitoring for toxic endpoints provides additional information on the effect of all chemicals, whether measured or not, and the response of aquatic communities to pollutant mixtures (Hunt et al., 2010).

The assessment of riparian habitats is also important for relating water quality to the adjacent terrestrial environment. Riparian habitats provide shelter, and regulate temperature, fluxes of organic matter, and energy in surface waters. They are particularly important in the survival of native fishes and are seasonally important to some amphibians, bird and mammal species (Bury, 1988).

What is the target or desired condition?

The target condition is for surface waters in the Santa Ana watershed to support their beneficial uses. The Santa Ana Regional Water Quality Control Board (SARWQCB) describes water quality objectives (WQOs) to protect the beneficial uses in the Water Quality Control Plan for the Santa Ana River Basin (SARWQCB, 1995). These WQOs are typically narrative or numeric limits above, or below, which a deleterious effect may be observed. This target condition would be supported by the absence of toxic endpoints and a riparian habitat that is in its best achievable state with respect to its physical, biological, and hydrological attributes.

What can influence or stress condition?

About 1/3 of the Santa Ana watershed is within the relatively undisturbed National Forests. Water quality in this area can be influenced by cycles of fire, drought, and flooding.

In urban areas, water quality is impacted by trash, bacteria, metals and a variety of chemicals that enter through storm drains and diffuse run-off (SWRCB, 2006). The SARWQCB has included surface waters of Reaches 2, 3 and 6 of the Santa Ana River, as well as many other tributaries and water bodies, on the Clean Water Act (CWA) 2010 §303(d) list of impaired water bodies.

Emerging contaminants (ECs), such as pharmaceuticals, insecticides, surfactants, endocrine disruptors, are also increasingly present in urban watersheds. These contaminants can have adverse effects on aquatic life and humans, even at trace levels. Drugs excreted or disposed to the domestic sewerage system, effluents from hospitals and runoff from animal husbandry are potential sources of ECs in urban watersheds.

Concrete channelization impacts riparian communities (SWRCB, 2006). The clearing of riparian vegetation can alter the functioning of river ecosystems and disrupt fluxes of organic matter and energy as well as the riffle/pool sequences that provide a diversity of habitats for aquatic species such as fish and invertebrates. Furthermore, these channel modifications directly affect water quality through increasing water temperature, changing the natural supply of fresh water to a water body, and altering the rates and paths of sediment erosion, transport, and deposition.

Basis of calculation and use

The Santa Ana Watershed, unlike the San Gabriel and Los Angeles watersheds, does not have a comprehensive watershed-wide monitoring program for surface water ambient conditions. Those two watersheds have programs of monitoring specifically designed to understand how management actions are impacting the beneficial uses of the system as a whole.

The Santa Ana River Watershed does have a comprehensive watershed-wide monitoring program for groundwater ambient conditions, however for surface water monitoring programs, monitoring programs are separated out based on subwatersheds associated with TMDLs listings for specific water bodies and stream reaches, WWTPs, discharges and MS4 stormwater. For this analysis of the Santa Ana, the 2011 report provided to SAWPA by Wildermuth Environmental was used to describe the ambient water quality for Nitrogen and TDS in groundwater within the Santa Ana watershed between 1990 and 2009.

What did we find out/How are we doing?

The Basin Plan for the Santa Ana requires water quality assessments every three years, for only total dissolved solids and for total inorganic nitrogen in groundwater. This procedure is not sufficient to provide water resource managers actionable guidance but does provide water quality trend information over time.

The score of this indicator was drawn from the 2011 report which suggested that 75% of the streams and reaches within the watershed were in compliance with the two assessed standards.

How sure are we about our findings (Things to keep in mind)

This score is developed from an overly simplified metric. A comprehensive monitoring program that assesses water chemistry, toxicity and riparian and aquatic habitat is necessary to properly describe the ambient conditions throughout the watershed.

Technical Information

Data Sources

Recomputation of Ambient Water Quality in the Santa Ana Watershed for the Period 1990 – 2009, prepared for the SAWPA Basin Monitoring Program Task Force by Wildermuth Environmental, August 2011.

Indicator 15: Exceedances of salinity standards in groundwater

What is it?

Imported water and agricultural runoff can be high in salts. Over time, as water is infiltrated to a groundwater basin and withdrawn through natural processes or pumping, the salts can accumulate. This indicator reveals that if the management of groundwater basins is properly mitigating for salts.

Assimilative capacity is the term used to describe the ability for a groundwater basin to receive additional salts without causing the basin to exceed the regulatory limits placed upon it. A basin with assimilative capacity is not in exceedance.

Why is it Important?

Managing the salinity of water in the groundwater basins is necessary to maintain the basin as a water supply storage location.

What is the target or desired condition?

All groundwater basins should have assimilative capacity or at least not exceed the historical ambient water quality.

What can influence or stress condition?

The type and amount of infiltrated water can impact the salt loading of a basin. Desalting operations also have impact, as do coastal seawater intrusion barrier operations.

Basis of calculation and use

The referenced data set used to evaluate the "Exceedances of salinity standards in surface or groundwater", was the Final Technical Memorandum - Recomputation of Ambient Water Quality in the Santa Ana Watershed for the Period 1990 to 2009 completed by Wildermuth Environmental in 2012. This report summarizes the efforts of stakeholders to estimate current TDS and Nitrate-N concentrations in each groundwater management zone within the Santa Ana River watershed, and is the third triennial recomputation in accordance with the 2004 Basin Plan Amendment.

The specific data used in this analysis are the assimilative capacities of TDS and nitrate-nitrogen computed over a 20 year period for each groundwater management zone in the Santa Ana River Watershed (see Table 15).

Table 15. Assimilative Capacities of TDS and Nitrate-Nitrogen

Management Zone	Computed Assimilative Capacity	
	TDS (mg/L)	Nitrate-N (mg/L)
Arlington	-40	-8.1
Beaumont	50	2.5
Bedford	--	--
Bunker Hill-A	60	-1.3
Bunker Hill-B	20	1.9
Canyon	-190	-0.2
Chino 1	-60	-4.1
Chino 2	-110	-7.4
Chino 3	-60	-4.9
Chino-East	-40	-5.7
Chino-North	80	-4.5
Chino-South	-300	-22.6
Coldwater	-60	-1.3
Colton	-20	-0.1
Cucamonga	130	0.9
Elsinore	10	-1.2
Hemet-South	-180	-1.1
Irvine	0	-0.8
La Habra	--	--
Lakeview/Hemet-North	-370	-0.8
Lee Lake	--	--
Lytle	20	-1.1
Menifee	-1030	-1.6
Orange County	-20	0.4

Perris-North	-200	-2.2
Perris-South	-1210	-3.3
Prado Basin	*	*
Rialto	0	-1.1
Riverside-A	130	1
Riverside-B	-50	-0.8
Riverside-C	-60	-6.5
Riverside-D	--	--
Riverside-E	20	-5.2
Riverside-F	90	-1.1
San Jacinto-Lower	-280	-0.1
San Jacinto-Upper	-30	-0.1
San Timoteo	-20	4.2
Santiago	--	--
Temescal	-20	-2
Warm Springs Valley	--	--
Yucaipa	50	-1.2
* surface water objective applies		

What did we find out/How are we doing?

Analysis of Table 15 shows that 46% of the groundwater management zones have assimilative capacity. The remaining have negative values, indicating that that may be trending towards further impairment.

How sure are we about our findings (Things to keep in mind)

The analysis associated with the ambient water quality update conducted every three years is detailed and thorough and one of the most detailed analyses of ambient conditions conducted for groundwater in watershed across the state. The causes of the trending towards exceedances of the ambient water quality may be due to a variety of causes and not necessarily anthropogenic such subsurface inflow from historically saltier groundwater management zones. Evaluating of the salt and nitrogen trends every three years allows the Regional Board to anticipate impacts and take action to control salt and nitrogen additions as needed. Since the changes in groundwater quality at the groundwater management scale are very gradual over time, the triennial monitoring of ambient water quality conditions should be adequate to track impacts.

Indicator 16: Exceedances of water quality objectives at monitored discharge points

What is it?

Anyone who discharges water into inland waterbodies or the ocean is subject to regulation under the Clean Water Act. In most cases, part of the permit provided under the National Pollution Discharge Elimination System (NPDES) to each discharger requires monitoring of water quality at the “outfall”, or, where the discharged waters enter the receiving waters. The data created by this monitoring is a very good source to describe how point-sources are being managed to maintain good water quality.

Why is it Important?

It is important to describe broadly the impacts on water quality that are created by human activity. Discharges into the water are one aspect of that impact, and because in Santa Ana watershed a significant volume of water enters the streams in this manner, it is critical that this indicator be considered.

What is the target or desired condition?

This indicator relies on the regulatory requirements placed upon the dischargers to describe the target condition.

What can influence or stress condition?

Wastewater treatment facilities and other industrial operations are impacted by any number of situations that can cause their treatment systems to produce exceedances in the discharged water. In most cases, these overages are temporary and well-managed when they do occur.

Basis of calculation and use

Any dischargers with NPDES permits provide monitoring data to the Santa Ana River Basin Regional Water Quality Control Board. Based on that monitoring data and the permit conditions, this indicator calculates the number of exceedances as-compared to the number of samples.

What did we find out/How are we doing?

At the time of this report, insufficient data was available to assess this indicator. Efforts are underway to determine if water quality data from NPDES permits that are submitted to the SARWQCB can be forwarded to SAWPA on a regular basis so that this indicator can be tracked in the future.

Indicator 17: Exceedances of water quality objectives at recreational use areas

What is it?

To provide recreational opportunities, the lakes and streams of the watershed must be clean enough to allow safe swimming. For water-based recreation, people must able and legally allowed to access the water. The Santa Ana Basin Plan designates which streams and water bodies have the beneficial uses of REC-1 or REC-2, both of which refer to water-related recreation. Waters designated as Water Contact Recreation (REC-1) beneficial use support recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, white water activities, fishing, or use of natural hot springs. Non-contact water recreation (REC-2) uses of water do not normally involve body contact with water, but ingestion of water is reasonably possible. In most cases, however, stream segments of Southern California have been channelized for flood management, and despite the recreational designation in the Basin Plan, they are made inaccessible by policy and statute.

When streams and lakes are swimmable and fishable, they provide recreational opportunities for people of the watershed. In California, it is the role the Regional Water Quality Control Boards to determine waters that are suitable for these activities and describe Water Quality Objectives (WQOs) to ensure that these waters are protected. In particular, at locations where people are in direct contact with the water, such as swimming and wading, bacterial pathogens should not exceed levels that pose a direct risk to human health. In addition, at locations where anglers are catching and consuming fish, pollutants should not bio-accumulate in fish tissues to levels that are harmful to human health.

Why is it Important?

E.coli belongs to a group of bacteria known as fecal coliforms that live in the lower intestines of warm-blooded mammals. The presence of E.coli in recreational waters indicates fecal contamination by humans or animals and can cause illness if accidentally ingested while swimming in the contaminated water. Although many strains of E.coli are harmless to humans, enterohemorrhagic strains such as 0157:H7 can cause bloody diarrhea, stomach cramps, nausea and vomiting and in more severe cases anemia, kidney failure and death in the elderly, the very young or the immunocompromised (Nataro, 1998). E.coli can also act as a freshwater diagnostic tool that may suggest the presence of other, more harmful, bacteria such as Salmonella, giardia, and others. These bacteria may cause illnesses such as gastro-intestinal distress including fever, vomiting, weight loss, typhoid and more.

What is the target or desired condition?

The Santa Ana Basin Plan requires that fecal coliform densities should not exceed 200 MPN/100 mL based on five or more samples in a 30-day period (SARWQCB. 1995). This protective standard was developed in line with human health standards that allow “historically acceptable illness rates,” which for freshwater bodies has been designated as eight illnesses per 1,000 swimmers (US EPA, 1986).

What can influence or stress condition?

Fecal material infected with E.coli can be introduced into recreational waters through accidental sewage spills, leaking sewage infrastructure, inappropriate disposal of pet/livestock wastes, or waste droppings from wildlife. In the Arroyo Seco watershed, swimming sites are located in the relatively undeveloped upper watershed, where sources of E.coli at these sites are most likely from humans, domestic animals, and wildlife (CREST, 2008). Therefore, an increase in the number of people swimming at these sites, particularly during peak holiday periods, as well an increase in the number of domestic animals and wildlife in these waters would likely result in increases in the levels of E.coli.

Basis of calculation and use

Monitoring at locations of REC1 and REC2 is necessary to assess the condition of this indicator. To date, a comprehensive effort to monitor freshwater swim sites within the Santa Ana watershed has not been attempted. However, as a result of the Stormwater Quality Standards Task Force and recently approved Basin Plan Amendments affecting the recreation and pathogen indicators, a comprehensive monitoring program has been proposed and is likely to be implemented in future years for the watershed. It is anticipated that this new monitoring program would be developed in conjunction with the monitoring programs currently conducted by various Pathogen TMDL task forces and the MS4 stormwater monitoring programs.

What did we find out/How are we doing?

Sufficient data is not available to assess this indicator at this time.

Indicator 18: Biological condition indicator

What is it?

The composition of plant, invertebrate, and vertebrate communities living in waterbodies can reveal whether the waterbodies are in good condition, or degraded as a result of human activity. The California Stream Condition Index uses the composition of invertebrate communities in the stream benthos as a measure of stream degradation (Ode et al.,). Scientists have surveyed over 3,000 streams in California for their invertebrate community composition, including reference and “test” (non-reference) streams. The CSCI is a composite of two indicators: 1) the ratio of observed to expected species and 2) a combination of metrics related to tolerance to pollution and disturbance.

Native fish richness and the presence of individual fish species are two indicators of stream health. Fish biologists have surveyed many of California's streams, lakes and rivers for the presence and/or absence of native and non-native fish. Fish indicators have been widely used and recognized as important tools to evaluate watershed and stream ecosystem health. A combination of native fish conservation status and the fish community composition will provide a complete evaluation of the fish condition in California watersheds. The indicator used in this evaluation is one of 4 proposed in the California Water Plan, Sustainability Indicators Framework: "Percentage of native richness expected." This indicator compares the native species richness to the expected number of fish species by main zoogeographic/watershed region1. The expected native richness by main watershed region is obtained from Moyle (2002), which provides the historic (pre-1850) native fish diversity. Native richness would be evaluated periodically in a 5-year period. The other possible indicators are "Conservation status of freshwater fish", "Status of key fish species", and "Proportion non-native species."

Why is it Important?

Degradation of the physical or chemical conditions in a water body can impact what plants and animals can live there, so investigating aquatic community structure and composition can help indicate condition of the water body. Invertebrate communities are not only valuable members of the aquatic fauna in their own right, they are food for larger creatures (e.g., fish) and are sensitive indicators of stream condition. Similarly, the presence and/or absence of native fish species can be used to evaluate stream condition. By measuring the biological integrity or health of a water body, managers and decision-makers can make sure that the water body is providing beneficial uses.

California has 129 native inland fishes, of which 63% are endemic to the state (Moyle et al 2011). Diverse conditions in California have produced fish species that have evolved and adapted independently in isolated watersheds. Fish communities, therefore, are important elements of the state freshwater ecosystems and their status and composition represent good indicators to evaluate disturbances over time. Comparison of the current "observed" native fish assemblage compared to the historical "expected" native fish community indicates how well the watershed or streams are doing in supporting the natural functional diversity.

What is the target or desired condition?

The CSCI compares test streams with reference streams of the same type and provides raw values in CA ranging from 0 to 1.21 (Ode et al.,). The highest value is not a theoretical maximum, it means that the stream with that value had a wide range of pollution-sensitive species at rates that were expected.

The desired condition for native fish communities is that they are fully intact (100% of expected native species are present), that they will conserve or resemble the historical natural assemblage, and there are no invasive species.

What can influence or stress condition?

There are several stressors of native aquatic communities in California, including: habitat conversion and degradation, impacts of anthropogenic activities, and introduced species. A recent analysis on the conservation status of native fish in California (Moyle et al 2011) concluded that even though each imperiled species has its own combination of causes of decline, there are two common stress factors: large-scale landscape changes (mainly invasive species, dams, agriculture and urbanization) and climate change. Sixty-two percent of threatened fish in California are affected by climate change, especially those species that rely on flows of cool water (< 20C).

Basis of calculation and use

The mean value for reference streams was 1.01, while the lower 5th percentile value for reference streams was 0.87. Streams ranged in values down to XX. The State Water Resources Control Board is considering adopting ranges of values constituting good health: >0.87, watch conditions: 0.72 – 0.87; and degraded conditions: <0.72. Rather than use 0.87 as the ideal condition equivalent to a score of 100, we used the mean reference condition of 1.01 to set the score of 100 and the 0.87 value to set a score of 90, with a linear relationship between CSCI value and score. The 0.72 CSCI value was made equivalent to a score of 50, and the CSCI value was made equivalent to a score of 0, with a linear relationship between 0 and 0.72.

- CSCI 0 = Score 0
- CSCI 0.72 = Score 50
- CSCI 0.87 = Score 90
- CSCI ≥1.01 = Score 100

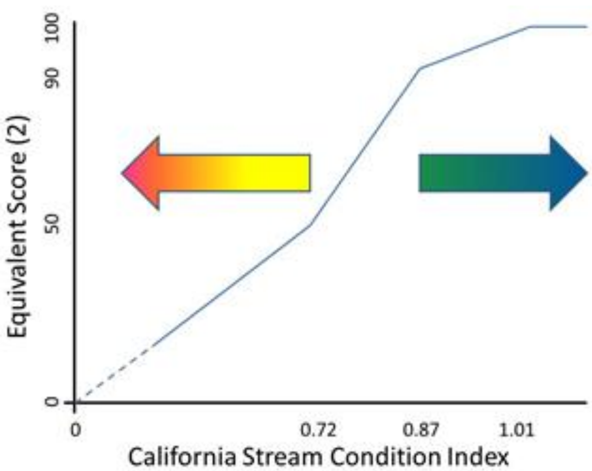

Figure 24. Scoring curve for the California Stream Condition Index.

What did we find out/How are we doing?

Although there are significant data gaps, in general, conditions for benthic macroinvertebrates and native fish are good in parts of the upper watershed and just upstream of Prado dam and generally poor in developed areas.

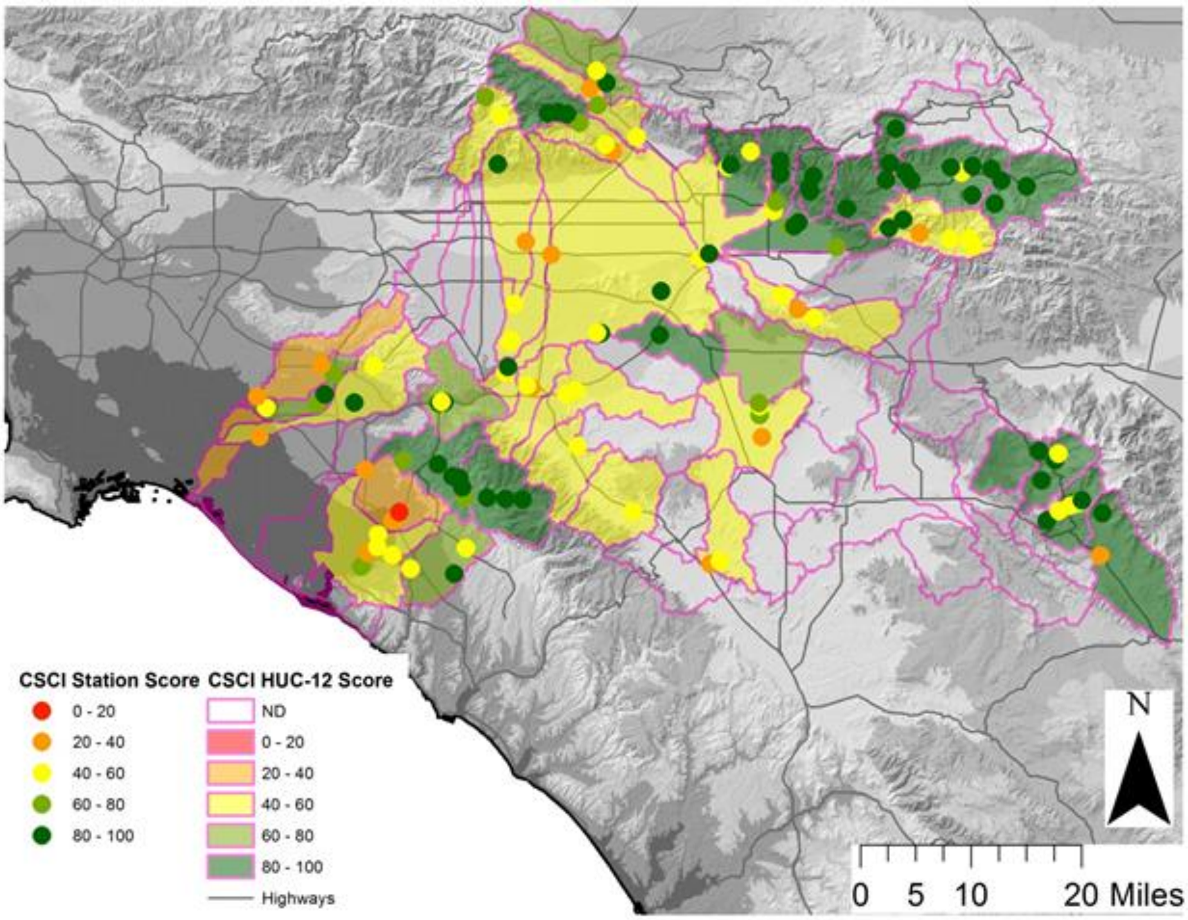

Figure 25. Biological indicator score for California Stream Condition Index for individual streams where benthic macroinvertebrates were sampled and the corresponding HUC-12 watershed.

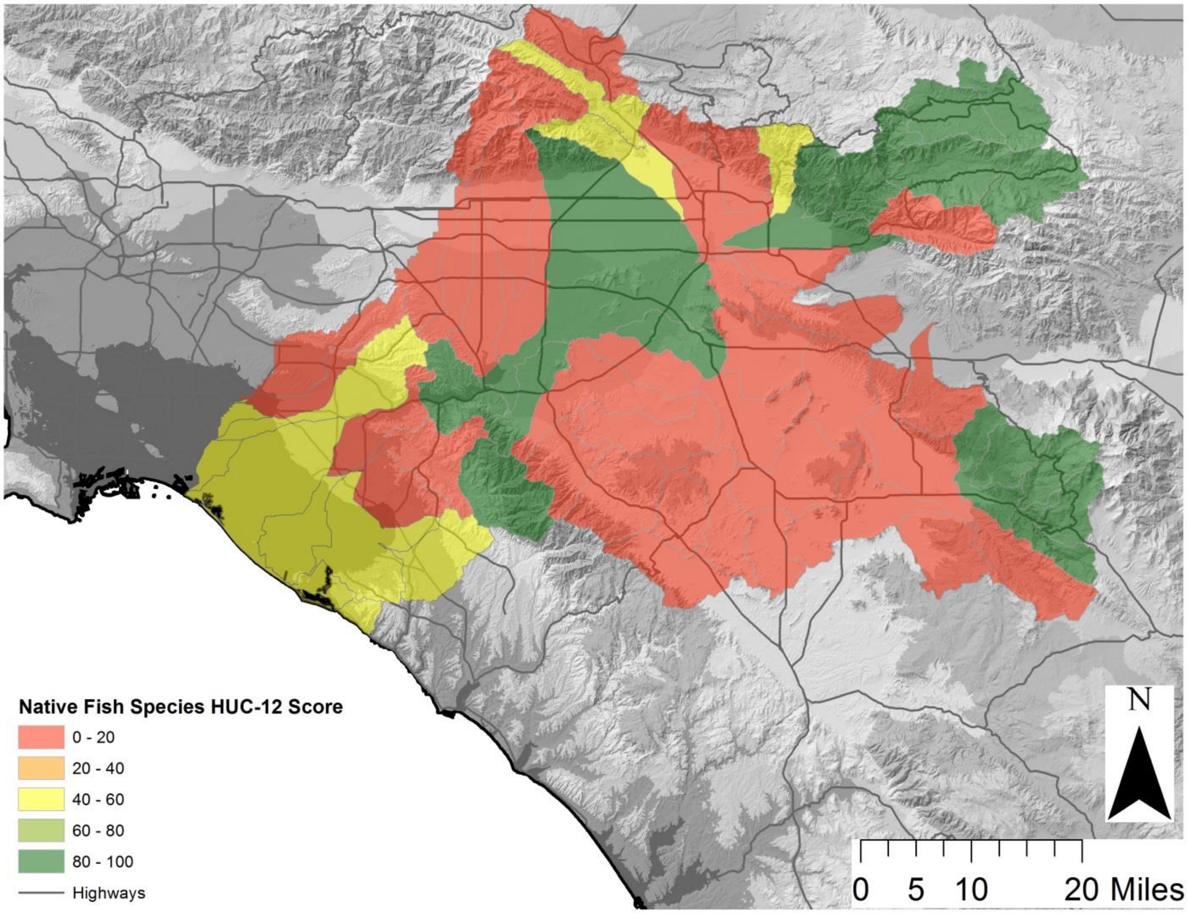

Figure 26. Biological indicator score for native fish presence per HUC-12 watershed.

Temporal and spatial resolution

Both the CSCI and fish surveys were conducted over several-year periods and are therefore not current. It is possible that conditions have improved or degraded in any individual stream or HUC-12 watershed. The spatial resolution is a mixture of accurate for individual streams where surveys were conducted and low accuracy when findings are extrapolated to larger areas. Both of these spatial and temporal issues can be resolved by more frequent and dispersed surveying of stream biota.

How sure are we about our findings (Things to keep in mind)

Both measures are excellent indicators of stream biological condition. Because of the difficulty in carrying out the surveying to inform each indicator, repeating these assessments requires that experts be retained.

Technical Information

Data Sources

All fish data, spatial or otherwise, for the observed over historic species ranges come from the Pisces Database – University of California, Davis.

This is a comprehensive database that is compiling California native and non-native fish data from different sources and public institutions. Up to date, Pisces' main sources of information are the long-term monitoring databases resulting from the studies of Prof. Peter Moyle in different watersheds throughout the state.

Data Transformations and Analysis

CSCI tabular and shapefile data were obtained directly from Peter Ode at the State Water Resources Control Board.

Native fish species presence data were downloaded from the Pisces database as spatial files for import into ArcGIS. We used Arc GIS spatial software to display the historic and observed ranges of native fish species throughout California. To illustrate effects on individual watersheds we used Hydrologic Unit Codes representing the smallest sub-watershed level (HUC 12).

Ranges were downloaded for all species in the Pisces database that had both historic and observed range data. These range maps were combined to create one database with columns included for range type, species, and species richness. This resulted in multiple species and range types for many of the HUC 12 watersheds in California.

Table 16. Range type, species, and species richness for multiple HUC-12 species

Range Type	Frequency
Historic and Observed	312
Observed	2594
Grand Total	2906

To create the observed over historic score, we simply divided the frequency of HUC 12 watersheds for each type. Ratios greater to or equal to 1 were given a score of 1, and the resulting ratios multiplied by 100 to give a range of 0-100.

There were several assumptions made in determining the results of our analysis. First, there are several species that have seasonal ranges. We used the full extent of the range, independent of the season. Also, subspecies were treated separately, i.e. as different species. This approach added to the species richness for either historic or observed distributions.

OWOW Sustainability Goal 5: Accomplish effective, equitable and collaborative integrated watershed management in a cost-effective manner

Indicator 19: OWOW Participation Statistics

What is it?

This indicator seeks to understand if the goal of having all stakeholders represented in the watershed management effort is being met. The Santa Ana watershed is massive, and contained a diverse community of people, businesses and governments. Assuring that the process is transparent, accessible, and representative is of great importance to the Pillars and SAWPA.

Why is it Important?

Integrated Water Management encourages an inclusive consensus process where all stakeholders are engaged to leverage resources, missions, and goals together. This holistic approach achieves greater efficiency and equity in the process of managing water resources.

What is the target or desired condition?

The target here is an integrated water management process that has representation from all communities in the watershed, that is open to any member of the community to participate, and that seeks best value for the watershed as a whole through resulting projects and programs.

What can influence or stress condition?

Integration and collaboration is time, labor and resource expensive. It is, however, high-value. The challenge of reorienting the management systems that engage with IWM to understand this is the largest stressor on the system.

Basis of calculation and use

A satisfactory indicator of this feature of OWOW has not yet been crafted. It must include a measure of participants in the process and their connection to the communities of the watershed. Gaps, where communities are not represented in the management group, should be highlighted for correction.

A second metric that explores the ability of interested community stakeholders to engage with the process is needed. Using open-meeting laws or the like, an assessment of how IWM-related meetings and processes are made open to the public is necessary.

Lastly, the distribution of VALUE from projects and programs should be completed. The dangers that the cost of projects becoming proxy for value, and the location of a project becoming the point of value must be avoided. Project and program value to the watershed as a whole, or to only a subsection, should be assessed, watching for inequities in the resulting value of OWOW projects and programs.

What did we find out/How are we doing?

This indicator was not assessed, as the data necessary is not currently being maintained.

Indicator 20: Performance of OWOW 1.0 selected projects

What is it?

This indicator looks at the required monitoring of OWOW projects to assess if the projects, as a group, are performing as was expected when they were selected for funding.

Why is it Important?

The OWOW process identified goals and objectives for the watershed, and then selected from a suite of projects those most likely to achieve the goals. Understanding if the goal setting and project selection processes are working to enhance IWM in the Santa Ana watershed is fundamental to an adaptive management process. The governance and decision-making of OWOW may need to be adjusted process of as past practice and future challenges force change.

What is the target or desired condition?

The target is that the performance of projects selected by the OWOW process properly align with the stated outcomes, and that the goals of the OWOW process are slowly achieved through integrated management.

What can influence or stress condition?

The complexity of the project of IWM in Santa Ana cannot be overstated. In this complex process, collaboration has generated goals and selected projects to help achieve those goals. Each project makes only discrete contributions to the overall effort. And, the system that is under management is constantly in flux through natural, economic and human activity. The stress on the integrated water management structure is great.

Basis of calculation and use

Each IWM project, during design phases, assesses the impact it will have on the watershed, along several lines of value. Those values and the goals of the project depend on the IWM management group. Each project that is then proposed for funding and built or implemented has monitoring requirements. In this indicator we propose that the projects outcome monitoring be compared to the assessment of potential value that was asserted during design phases. As a whole, then, how are the projects fairing? Are the goals of the IWM process being met with the projects that same management team selected for execution?

What did we find out/How are we doing?

This indicator was not scored, for lack of a sufficient data set.

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